# EXTRACTS

FROM

# MAN AND NATURE,

OR

## THE EARTH AS MODIFIED BY HUMAN ACTION,

BY

G. P. MARSH:

WITH SOME NOTES ON

## FORESTS AND RAIN-FALL IN MADRAS,

BY

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# PREFACE.

THE following extracts from "Man and Nature," are, I think, of much interest at any time, but of more than usual interest now that a Forest Law is in active preparation for the Madras Presidency, and it is generally felt that the question of the Forest has not received that attention which it deserves, and that more is required than has been possible to carry out up to the present time. Through the kindness of His Excellency the Governor of Madras, who has been so good as to obtain for me the permission of the author very kindly and liberally given as well as some additional notes by him which have until now never been in print, I am able to put into the reader's hands in a convenient form a series of extracts including the most interesting portions of Mr. Marsh's work bearing upon the Forests, and I hope these will meet with the favor I think they deserve at the hands of a discerning public.

Appended will be found a memorandum of my own on the Forests and Rain-fall of the Madras Presidency which may be divided into two parts,—the first, is an application more or less direct of principles to be found in detail in Marsh's work to the facts as they appear to me of this part of India; the second, an attempt to trace the origin and causes of rain, and how these are affected by the presence or absence of Forest with reference in particular to

India. The reader will please remember that these pages are but suggestions thrown out for general consideration and discussion on a most difficult but interesting subject, upon which it would be presumption on my part to say more than that they may perhaps be found to contain some ideas on the subject which may commend themselves to those who have carefully and scientifically studied the subject. If they lead to some useful discussion, they will have fulfilled their purpose.

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# THE EARTH AS MODIFIED BY HUMAN ACTION,

By G. P. MARSH.

After discussing the uncertainty of Meteorological data, the author proceeds to the

## Mechanical Effects produced by Man on the surface of the Earth.

In investigating the mechanical effects of human action on superficial geography, we are treading on safer ground, and dealing with much less subtile phenomena, less intractable elements. Great physical changes can, in some cases, be positively shown, in some almost certainly inferred, to have been produced by the operations of rural industry, and by the labors of man in other spheres of material effort; and hence, in this most important part of our subject, we can arrive at many positive generalizations, and obtain practical results of no small economical value. Many circumstances conspire to invest with great present interest the questions: how far man can permanently modify and ameliorate those physical conditions of terrestrial surface and climate on which his material welfare depends; how far he can compensate, arrest, or retard the deterioration which many of his agricultural and industrial processes tend to produce; and how far he can restore fertility

and salubrity to soils which his follies or his crimes have made barren or pestilential.

## STABILITY OF NATURE.

Nature, left undisturbed, so fashions her territory as to give it almost unchanging permanence of form, outline, and proportion, except when shattered by geologic convulsions; and in these comparatively rare cases of derangement, she sets herself at once to repair the superficial damage, and to restore, as nearly as practicable, the former aspect of her dominion. In new countries, the natural inclination of the ground, the self-formed slopes and levels, are generally such as best secure the stability of the soil. They have been graded and lowered or elevated by frost and chemical forces and gravitation and the flow of water and vegetable deposit and the action of the winds, until, by a general compensation of conflicting forces, a condition of equilibrium has been reached which, without the action of man, would remain, with little fluctuation, for countless ages.

We need not go far back to reach a period when, in all that portion of the North American continent which has been occupied by British colonization, the geographical elements very nearly balanced and compensated each other. At the commencement of the seventeenth century, the soil, with insignificant exceptions, was covered with forests; and whenever the Indian, in consequence of war or the exhaustion of the beasts of the chase, abandoned the narrow fields he had planted and the woods he had burned over, they speedily returned, by a succession of herbaceous, arborescent, and arboreal growths, to their original state. Even a single generation sufficed to restore them almost to their primitive luxuriance of forest vegetation. The unbroken forests had attained to their maximum density and strength of growth, and, as the older trees decayed and fell, they were

succeeded by new shoots or seedlings, so that from century to century no perceptible change seems to have occurred in the wood, except the slow, spontaneous succession of crops. This succession involved no interruption of growth, and but little break in the "boundless contiguity of shade;" for, in the husbandry of nature, there are no fallows. Trees fall singly, not by square roods, and the tall pine is hardly prostrate, before the light and heat, admitted to the ground by the removal of the dense crown of foliage which had shut them out, stimulate the germination of the seeds of broad-leaved trees that had lain, waiting this kindly influence, perhaps for centuries.

Young trees in the native forest are sometimes girdled and killed by the smaller rodent quadrupeds, and their growth is checked by birds which feed on the terminal bud; but these animals, as we shall see, are generally found on the skirts of the wood only, not in its deeper recesses, and hence the mischief they do is not extensive. The insects which damage primitive forests by feeding upon products of trees essential to their growth, are not numerous, nor is their appearance, in destructive numbers, frequent; and those which perforate the stems and branches, to deposit and hatch their eggs, more commonly select dead trees for that purpose, though, unhappily, there are important exceptions to this latter remark. I do not know that we have any evidence of the destruction or serious injury of American forests by insects, before or even soon after the period of colonization; but since the white man has laid bare a vast proportion of the earth's surface, and thereby produced changes favorable, perhaps, to the multiplication of these pests, they have greatly increased in numbers, and, apparently, in voracity also. Not many years ago, the pines on thousands of acres of land in North Carolina, were destroyed by insects

not known to have ever done serious injury to that tree before. In such cases as this and others of the like sort, there is good reason to believe that man is the indirect cause of an evil for which he pays so heavy a penalty. Insects increase whenever the birds which feed upon them disappear. Hence, in the wanton destruction of the robin and other insectivorous birds, the *bypes implumis*, the featherless biped, man, is not only exchanging the vocal orchestra which greets the rising sun for the drowsy beetle's evening drone, and depriving his groves and his fields of their fairest ornament, but he is waging a treacherous warfare on his natural allies.

In fine, in countries untrodden by man, the proportions and relative positions of land and water, the atmospheric precipitation and evaporation, the thermometric mean, and the distribution of vegetable and animal life, are subject to change only from geological influences so slow in their operation that the geographical conditions may be regarded as constant and immutable. These arrangements of nature it is, in most cases, highly desirable substantially to maintain, when such regions become the seat of organized commonwealths. It is, therefore, a matter of the first importance, that, in commencing the process of fitting them for permanent civilized occupation, the transforming operations should be so conducted as not unnecessarily to derange and destroy what, in too many cases, it is beyond the power of man to rectify or restore.

## Restoration of Disturbed Harmonies.

In reclaiming and re-occupying lands laid waste by human improvidence or malice, and abandoned by man, or occupied only by a nomade or thinly scattered population, the task of the pioneer settler is of a very different character. He is to become a co-worker with nature in the reconstruction of the

damaged fabric which the negligence or the wantonness of former lodgers has rendered untenantable. He must aid her in reclothing the mountain slopes with forests and vegetable mould, thereby restoring the fountains which she provided to water them; in checking the devastating fury of torrents and bringing back the surface drainage to its primitive narrow channels; and in drying deadly morasses by opening the natural sluices which have been choked up, and cutting new canals for drawing off their stagnant waters. He must thus, on the one hand, create new reservoirs, and, on the other, remove mischievous accumulations of moisture, thereby equalizing and regulating the sources of atmospheric humidity and of flowing water, both which are so essential to all vegetable growth, and, of course, to human and lower animal life.

### Destructiveness of Man.

Man has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste. Nature has provided against the absolute destruction of any of her elementary matter, the raw material of her works; the thunderbolt and the tornado, the most convulsive throes of even the valcano and the earthquake, being only phenomena of decomposition and recomposition. But she has left it within the power of man irreparably to derange the combinations of inorganic matter and of organic life, which through the night of æons she had been proportioning and balancing, to prepare the earth for his habitation, when, in the fulness of time, his Creator should call him forth to enter into its possession.

Apart from the hostile influence of man, the organic and the inorganic world are, as I have remarked, bound together by such mutual relations and adaptations as secure, if not the absolute per-

manence and equilibrium of both, a long continuance of the established conditions of each at any given time and place, or at least, a very slow and gradual succession of changes in those conditions. But man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords. The proportions and accommodations which insured the stability of existing arrangements are overthrown. Indigenous vegetable and animal species are extirpated, and supplanted by others of foreign origin, spontaneous production is forbidden or restricted, and the face of the earth is either laid bare or covered with a new and reluctant growth of vegetable forms, and with alien tribes of animal life. These intentional changes and substitutions constitute, indeed, great revolutions; but vast as is their magnitude and importance, they are, as we shall see, insignificant in comparison with the contingent and unsought results which have flowed from them.

The fact that, of all organic beings, man alone is to be regarded as essentially a destructive power, and that he wields energies to resist which, nature—that nature whom all material life and all inorganic substance obey—is wholly impotent, tends to prove that, though living in physical nature, he is not of her, that he is of more exalted parentage, and belongs to a higher order of existences than those born of her womb and submissive to her dictates.

There are, indeed, brute destroyers, beasts and birds and insects of prey—all animal life feeds upon, and, of course, destroys other life,—but this destruction is balanced by compensations. It is, in fact, the very means by which the existence of one tribe of animals or of vegetables is secured against being smothered by the encroachments of another; and the productive powers of species, which serve as the food of others, are always proportioned to the demand they are destined to supply. Man pursues

his victims with reckless destructiveness; and, while the sacrifice of life by the lower animals is limited by the cravings of appetite, he unsparingly persecutes, even to extirpation, thousands of organic forms which he cannot consume.

The earth was not, in its natural condition, completely adapted to the use of man, but only to the sustenance of wild animals and wild vegetation. These live, multiply their kind in just proportion, and attain their perfect measure of strength and beauty, without producing or requiring any change in the natural arrangements of surface, or in each other's spontaneous tendencies, except such mutual repression of excessive increase as may prevent the extirpation of one species by the encroachments of another. In short, without man, lower animal and spontaneous vegetable life would have been constant in type, distribution, and proportion, and the physical geography of the earth would have remained undisturbed for indefinite periods, and been subject to revolution only from possible, unknown cosmical causes, or from geological action.

But man, the domestic animals that serve him, the field and garden plants the products of which supply him with food and clothing, cannot subsist and rise to the full development of their higher properties, unless brute and unconscious nature be effectually combated, and, in a great degree, vanquished by human art. Hence, a certain measure of transformation of terrestrial surface, of suppression of natural, and stimulation of artificially modified productivity becomes necessary. This measure man has unfortunately exceeded. He has felled the forests whose net work of fibrous roots bound the mould to the rocky skeleton of the earth; but had he allowed here and there a belt of woodland to reproduce itself by spontaneous propagation, most of the mischiefs which his reckless destruction of the natural protec-

tion of the soil has occasioned would have been averted. He has broken up the mountain reservoirs, the percolation of whose waters through unseen channels supplied the fountains that refreshed his cattle and fertilized his fields; but he has neglected to maintain the cisterns and the canals of irrigation which a wise antiquity had constructed to neutralize the consequences of its own imprudence. While he has torn the thin glebe which confined the light earth of extensive plains, and has destroyed the fringe of semi-aquatic plants which skirted the coast and checked the drifting of the sea sand, he has failed to prevent the spreading of the dunes by clothing them with artificially propagated vegetation. He has ruthlessly warred on all the tribes of animated nature whose spoil he could convert to his own uses, and he has not protected the birds which prey on the insects most destructive to his own harvests.

Purely untutored humanity, it is true, interferes comparatively little with the arrangements of nature, and the destructive agency of man becomes more and more energetic and unsparing as he advances in civilization, until the impoverishment, with which his exhaustion of the natural resources of the soil is threatening him, at last awakens him to the necessity of preserving what is left, if not of restoring what has been wantonly wasted. The wandering savage grows no cultivated vegetable, fells no forest, and extirpates no useful plant, no noxious weed. If his skill in the chase enables him to entrap numbers of the animals on which he feeds, he compensates this loss by destroying also the lion, the tiger, the wolf, the otter, the seal, and the eagle, thus indirectly protecting the feebler quadrupeds and fish and fowls, which would otherwise become the booty of beasts and birds of prey. But with stationary life, or rather with the pastoral state, man at once commences an almost indiscriminate warfare upon all the forms of

animal and vegetable existence around him, and as he advances in civilization, he gradually eradicates or transforms every spontaneous product of the soil he occupies.

## HUMAN AND BRUTE ACTION COMPARED.

It has been maintained by authorities as high as any known to modern science, that the action of man upon nature, though greater in *degree*, does not differ in *kind*, from that of wild animals. It appears to me to differ in essential-character, because, though it is often followed by unforeseen and undesired results, yet it is nevertheless guided by a self-conscious and intelligent will aiming as often at secondary and remote as at immediate objects. The wild animal, on the other hand, acts instinctively, and, so far as we are able to perceive, always with a view to single and direct purposes. The backwoodsman and the beaver alike fell trees; the man that he may convert the forest into an olive grove that will mature its fruit only for a succeeding generation, the beaver that he may feed upon their bark or use them in the construction of his habitation. Human differs from brute action, too, in its influence upon the material world, because it is not controlled by natural compensations and balances. Natural arrangements, once disturbed by man, are not restored until he retires from the field, and leaves free scope to spontaneous recuperative energies; the wounds he inflicts upon the material creation are not healed until he withdraws the arm that gave the blow. On the other hand, I am not aware of any evidence that wild animals have ever destroyed the smallest forest, extirpated any organic species or modified its natural character, occasioned any permanent change of terrestrial surface, or produced any disturbance of physical conditions which nature has not, of herself, repaired without the expulsion of the animal that had caused it.

The form of geographical surface, and very probably the climate of a given country, depend much on the character of the vegetable life belonging to it. Man has, by domestication, greatly changed the habits and properties of the plants he rears; he has, by voluntary selection, immensely modified the forms and qualities of the animated creatures that serve him; and he has, at the same time, completely rooted out many forms of animal if not of vegetable being. What is there, in the influence of brute life, that corresponds to this? We have no reason to believe that in that portion of the American continent which, though peopled by many tribes of quadruped and fowl, remained uninhabited by man, or only thinly occupied by purely savage tribes, any sensible geographical change had occurred within twenty centuries before the epoch of discovery and colonization, while, during the same period, man had changed millions of square miles, in the fairest and most fertile regions of the Old World, into the barrenest deserts.

The ravages committed by man subvert the relations and destroy the balance which nature had established between her organized and her inorganic creations; and she avenges herself upon the intruder, by letting loose upon her defaced provinces destructive energies hitherto kept in check by organic forces destined to be his best auxiliaries, but which he has unwisely dispersed and driven from the field of action. When the forest is gone, the great reservoir of moisture stored up in its vegetable mould is evaporated, and returns only in deluges of rain to wash away the parched dust into which that mould has been converted. The well-wooded and humid hills are turned to ridges of dry rock, which encumbers the low grounds and chokes the water-courses with its debris, and—except in countries favored with an equable distribution of rain through the seasons, and

a moderate and regular inclination of surface—the whole earth, unless rescued by human art from the physical degradation to which it tends, becomes an assemblage of bald mountains, of barren, turfless hills, and of swampy malarious plains. There are parts of Asia Minor, of Northern Africa, of Greece, and even of Alpine Europe, where the operation of causes set in action by man has brought the face of the earth to a desolation almost as complete as that of the moon; and though, within that brief space of time which we call "the historical period," they are known to have been covered with luxuriant woods, verdant pastures, and fertile meadows, they are now too far deteriorated to be reclaimable by man, nor can they become again fitted for human use, except through great geological changes, or other mysterious influences or agencies of which we have no present knowledge, and over which we have no prospective control. The earth is fast becoming an unfit home for its noblest inhabitant, and another era of equal human crime and human improvidence, and of like duration with that through which traces of that crime and that improvidence extend, would reduce it to such a condition of impoverished productiveness, of shattered surface, of climatic excess, as to threaten the depravation, barbarism, and perhaps even extinction of the species.

## Physical Improvement.

True, there is a partial reverse to this picture. On narrow theatres, new forests have been planted; inundations of flowing streams restrained by heavy walls of masonry and other constructions; torrents compelled to aid, by depositing the slime with which they are charged, in filling up lowlands, and raising the level of morasses which their own overflows had created; ground submerged by the encroachments of the ocean, or exposed to be covered by its tides,

has been rescued from its dominion by diking; swamps and even lakes have been drained, and their beds brought within the domain of agricultural industry; drifting coast dunes have been checked and made productive by plantation; seas and inland waters have been re-peopled with fish, and even the sands of the Sahara have been fertilized by artesian fountains. These achievements are more glorious than the proudest triumphs of war, but, thus far, they give but faint hope that we shall yet make full atonement for our spendthrift waste of the bounties of nature.

It is, on the one hand, rash and unphilosophical to attempt to set limits to the ultimate power of man over inorganic nature, and it is unprofitable, on the other, to speculate on what may be accomplished by the discovery of now unknown and unimagined natural forces, or even by the invention of new arts and new processes. But since we have seen aerostation, the motive power of elastic vapours, the wonders of modern telegraphy, the destructive explosiveness of gunpowder, and even of a substance so harmless, unresisting, and inert as cotton, nothing in the way of mechanical achievement seems impossible, and it is hard to restrain the imagination from wandering forward a couple of generations to an epoch when our descendants shall have advanced as far beyond us in physical conquest, as we have marched beyond the trophies erected by our grandfathers.

I must therefore be understood to mean only, that no agencies now known to man and directed by him seem adequate to the reducing of great Alpine precipices to such slopes as would enable them to support a vegetable clothing, or to the covering of large extents of denuded rock with earth, and planting upon them a forest growth. But among the mysteries which science is yet to reveal, there may be still undiscovered methods of accomplishing even grander

wonders than these. Mechanical philosophers have suggested the possibility of accumulating and treasuring up for human use some of the greater natural forces, which the action of the elements puts forth with such astonishing energy. Could we gather, and bind, and make subservient to our control, the power which a West Indian hurricane exerts through a small area in one continuous blast, or the momentum expended by the waves, in a tempestuous winter, upon the break water at Cherbourg, or the lifting power of the tide, for a month, at the head of the Bay of Fundy, or the pressure of a square mile of seawater at the depth of five thousand fathoms, or a moment of the might of an earthquake or a volcano, our age—which moves no mountains and casts them into the sea by faith alone—might hope to scrape the rugged walls of the Alps and Pyrenees and Mount Taurus, robe them once more in a vegetation as rich as that of their pristine woods, and turn their wasting torrents into refreshing streams.

Could this old world, which man has overthrown, be rebuilded, could human cunning rescue its wasted hill sides and its deserted plains from solitude or mere nomade occupation, from barrenness, from nakedness, and from insalubrity, and restore the ancient fertility and healthfulness of the Etruscan sea coast, the Compagna and the Poutine marshes, of Calabria of Sicily, of the Peloponnesus and insular and continental Greece, of Asia Minor, of the slopes of Lebanon and Hermon, of Palestine, of the Syrian desert, of Mesopotamia and the delta of the Euphrates, of the Cyrenaica, of Africa proper, Numidia, and Mauritania, the thronging millions of Europe might still find room on the Eastern continent, and the main current of emigration be turned toward the rising instead of the setting sun.

But changes like these must await great political and moral revolutions in the governments and peo-

ples by whom those regions are now possessed, a command of pecuniary and of mechanical means not at present enjoyed by those nations, and a more advanced and generally diffused knowledge of the processes by which the amelioration of soil and climate is possible, than now any where exists. Until such circumstances shall conspire to favor the work of geographical regeneration, the countries I have mentioned, with here and there a local exception, will continue to sink into yet deeper desolation, and in the meantime, the American continent, Southern Africa, Australia, and the smaller oceanic islands, will be almost the only theatres where man is engaged, on a great scale, in transforming the face of nature.

## Arrest of Physical Decay of new Countries.

Comparatively short as is the period through which the colonization of foreign lands by European emigrants extends, great, and, it is to be feared, sometimes irreparable, injury has been already done in the various processes by which man seeks to subjugate the virgin earth; and many provinces, first trodden by the *homo sapiens Europæ* within the last two centuries, begin to show signs of that melancholy dilapidation which is now driving so many of the peasantry of Europe from their native hearths. It is evidently a matter of great moment, not only to the population of the states where these symptoms are manifesting themselves, but to the general interests of humanity, that this decay should be arrested, and that the future operations of rural husbandry and of forest industry, in districts yet remaining substantially in their native condition, should be so conducted as to prevent the widespread mischiefs which have been elsewhere produced by thoughtless or wanton destruction of the natural safeguards of the soil. This can be done only by the diffusion of

knowledge on this subject among the classes that, in earlier days, subdued and tilled ground in which they had no vested rights, but who, in our time, own their woods, their pastures, and their ploughlands as a perpetual possession for them and theirs, and have, therefore, a strong interest in the protection of their domain against deterioration.

## Forms and Formations most liable to Physical Degradation.

The character and extent of the evils under consideration depend very much on climate and the natural forms and constitution of surface. If the precipitation, whether great or small in amount, be equally distributed through the seasons, so that there are neither torrential rains nor parching droughts, and if, further, the general inclination of ground be moderate, so that the superficial waters are carried off without destructive rapidity of flow, and without sudden accumulation in the channels of natural drainage, there is little danger of the degradation of the soil in consequence of the removal of forest or other vegetable covering, and the natural face of the earth may be considered as substantially permanent. These conditions are well exemplified in Ireland, in a great part of England, in extensive districts in Germany and France, and, fortunately, in an immense proportion of the valley of the Mississippi and the basin of the great American lakes, as well as in many parts of the continents of South America and of Africa.

Destructive changes are most frequent in countries of irregular and mountainous surface, and in climates where the precipitation is confined chiefly to a single season, and where the year is divided into a wet and a dry period, as is the case throughout a great part of the Ottoman empire, and, more or less strictly, the whole Mediterranean basin. It is partly, though

by no means entirely, owing to topographical and climatic causes that the blight, which has smitten the fairest and most fertile provinces of Imperial Rome, has spared Britannia, Germania, Pannonia, and Mœsia, the comparatively inhospitable homes of barbarous races, who, in the days of the Cæsars, were too little advanced in civilized life to possess either the power or the will to wage that war against the order of nature which seems, hitherto, an almost inseparable condition precedent of high social culture, and of great progress in fine and mechanical art.

In mountainous countries, on the other hand, various causes combine to expose the soil to constant dangers. The rain and snow usually fall in great quantity, and with much inequality of distribution; the snow on the summits accumulates for many months in succession, and then is not unfrequently almost wholly dissolved in a single thaw, so that the entire precipitation of months is in a few hours hurried down the flanks of the mountains, and through the ravines that furrow them; the natural inclination of the surface promotes the swiftness of the gathering currents of diluvial rain and of melting snow, which soon acquire an almost irresistible force and power of removal and transportation; the soil itself is less compact and tenacious than that of the plains, and if the sheltering forest has been destroyed, it is confined by few of the threads and ligaments by which nature had bound it together, and attached it to the rocky groundwork. Hence every considerable shower lays bare its roods of rock, and the torrents sent down by the thaws of spring, and by occasional heavy discharges of the summer and autumnal rains, are seas of mud and rolling stones that sometimes lay waste, and bury beneath them acres, and even miles, of pasture and field and vineyard.

## Birds as Sowers and Consumers of Seeds, and as Destroyers of Insects.

Wild birds form of themselves a very conspicuous and interesting feature in the *staffage*, as painters call it, of the natural landscape, and they are important elements in the view we are taking of geography, whether we consider their immediate or their incidental influence. Birds affect vegetation directly by sowing seeds and by consuming them; they affect it indirectly by destroying insects injurious, or, in some cases, beneficial to vegetable life. Hence, when we kill a seed-sowing bird, we check the dissemination of a plant; when we kill a bird which digests the seed it swallows, we promote the increase of a vegetable. Nature protects the seeds of wild, much more effectually than those of domesticated plants. The cereal grains are completely digested when consumed by birds, but the germ of the smaller stone fruits and of very many other wild vegetables is uninjured, perhaps even stimulated to more vigorous growth, by the natural chemistry of the bird's stomach. The power of flight and the restless habits of the bird enable it to transport heavy seeds to far greater distances than they could be carried by the wind. A swift-winged bird may drop cherrystones a thousand miles from the tree they grow on; a hawk, in tearing a pigeon, may scatter from its crop the still fresh rice it had swallowed at a distance of ten degrees of latitude, and thus the occurrence of isolated plants in situations where their presence cannot otherwise well be explained, is easily accounted for. There is a large class of seeds apparently specially fitted by nature for dissemination by animals. I refer to those which attach themselves, by means of hooks, or by viscous juices, to the coats of quadrupeds and the feathers of birds, and are thus transported wherever their living vehicles may chance to wander. Some birds, too, deliberately

bury seeds, not indeed with a foresight aiming directly at the propagation of the plant, but from apparently purposeless secretiveness, or as a mode of preserving food for future use.

An unfortunate popular error greatly magnifies the injury done to the crops of grain and leguminous vegetables by wild birds. Very many of those generally supposed to consume large quantities of the seeds of cultivated plants really feed almost exclusively upon insects, and frequent the wheat fields, not for the sake of the grain, but for the eggs, larvæ, and fly of the multiplied tribes of insect life which are so destructive to the harvests. This fact has been so well established by the examination of the stomachs of great numbers of birds in Europe and New England, at different seasons of the year, that it is no longer open to doubt, and it appears highly probable that even the species which consume more or less grain generally make amends, by destroying insects whose ravages would have been still more injurious. On this subject, we have much other evidence besides that derived from dissection. Direct observation has shown, in many instances, that the destruction of wild birds has been followed by a great multiplication of noxious insects, and, on the other hand, that these latter have been much reduced in numbers by the protection and increase of the birds that devour them. Many interesting facts of this nature have been collected by professed naturalists, but I shall content myself with a few taken from familiar and generally accessible sources. The following extract is from Michelet, L'Oiseau, pages 169, 170:

"The *stingy* farmer—an epithet justly and feelingly bestowed by Virgil. Avaricious, blind, indeed, who proscribes the birds—those destroyers of insects, those defenders of his harvests. Not a grain for the

creature which, during the rains of winter, hunts the future insect, finds out the nests of the larvæ, examines, turns over every leaf, and destroys, every day, thousands of incipient caterpillars. But sacks of corn for the mature insect, whole fields for the grasshoppers, which the bird would have made war upon. With eyes fixed upon his furrow, upon the present moment only, without seeing and without foreseeing, blind to the great harmony which is never broken with impunity, he has everywhere demanded or approved laws for the extermination of that necessary ally of his toil—the insectivorous bird. And the insect has well avenged the bird. It has become necessary to revoke in haste the proscription. In the Isle of Bourbon, for instance, a price was set on the head of the martin; it disappeared, and the grasshoppers took possession of the island, devouring, withering, scorching with a biting drought all that they did not consume. In North America it has been the same with the starling, the protector of Indian corn. Even the sparrow, which really does attack grain, but which protects it still more, the pilferer, the outlaw, loaded with abuse and smitten with curses—it has been found in Hungary that they were likely to perish without him, that he alone could sustain the mighty war against the beetles and the thousand winged enemies that swarm in the lowlands; they have revoked the decree of banishment, recalled in haste this valiant militia, which, though deficient in discipline, is nevertheless the salvation of the country.

"Not long since, in the neighbourhood of Rouen and in the valley of Monville, the blackbird was for sometime proscribed. The beetles profited well by this proscription; their larvæ, infinitely multiplied, carried on their subterranean labors with such success, that a meadow was shown me, the surface of which was completely dried up, every herbaceous

root was consumed, and the whole grassy mantle, easily loosened, might have been rolled up and carried away like a carpet."

## Diminution and Extirpation of Birds.

The general hostility of the European populace to the smaller birds is, in part, the remote effect of the reaction created by the game laws. When the restrictions imposed upon the chase by those laws were suddenly removed in France, the whole people at once commenced a destructive campaign against every species of wild animal. Arthur Young, writing in Provence, on the 30th of August, 1789, soon after the National Assembly had declared the chase free, thus complains of the annoyance he experienced from the use made by the peasantry of their newly won liberty: "One would think that every rusty firelock in all Provence was at work in the indiscriminate destruction of all the birds. The wadding buzzed by my ears, or fell into my carriage, five or six times in the course of the day." "The declaration of the Assembly that every man is free to hunt on his own land has filled all France with an intolerable cloud of sportsmen. The declaration speaks of compensations and indemnities [to the *seigneurs*], but the ungovernable populace takes advantage of the abolition of the game laws and laughs at the obligation imposed by the decree."

The French Revolution removed similar restrictions, with similar results, in other countries. The habits then formed have become hereditary on the continent, and though game laws still exist in England, there is a little doubt that the blind prejudices of the ignorant and half-educated classes in that country against birds are, in some degree, at least, due to a legislation, which, by restricting the chase of all game worth killing, drives the unprivileged sportsman to indemnify himself by slaughter-

ing all wild life which is not reserved for the amusement of his betters. Hence the lord of the manor buys his partridges and his hares by sacrificing the bread of his tenants, and so long as the farmers of Crawley are forbidden to follow higher game, they will suicidally revenge themselves by destroying the sparrows which protect their wheatfields.

On the continent, and especially in Italy, the comparative scarcity and dearness of animal food combine with the feeling I have just mentioned to stimulate still further the destructive passions of the fowler. In the Tuscan Province of Grosseto, containing less than two thousand square miles, nearly 300,000 thrushes and other small birds are annually brought to market.

Birds are less hardy in constitution, they possess less facility of accommodation, and they are more severely affected by climatic excess than quadrupeds. Besides, they generally want the means of shelter against the inclemency of the weather and against pursuit by their enemies, which holes and dens afford to burrowing animals and to some larger beasts of prey. The egg is exposed to many dangers before hatching, and the young bird is especially tender, defenceless, and helpless. Every cold rain, every violent wind, every hailstorm during the breeding season, destroys hundreds of nestlings, and the parent often perishes with her progeny while brooding over it in the vain effort to protect it. The great proportional numbers of birds, their migratory habits, and the ease with which they may escape most dangers that beset them, would seem to secure them from extirpation, and even from very great numerical reduction. But experience shows that when not protected by law, by popular favor or superstition, or by other special circumstances, they yield very readily to the hostile influences of civilization, and, though the first operations of the settler are

favorable to the increase of many species, the great extension of rural and of mechanical industry is, in a variety of ways, destructive even to tribes not directly warred upon by man.

Nature sets bounds to the disproportionate increase of birds, while at the same time, by the multitude of their resources, she secures them from extinction through her own spontaneous agencies. Man both preys upon them and wantonly destroys them. The delicious flavour of game birds, and the skill implied in the various arts of the sportsman who devotes himself to fowling, make them favorite objects of the chase, while the beauty of their plumage, as a military and feminine decoration, threatens to involve the sacrifice of the last survivor of many once numerous species. Thus far, but few birds described by ancient or modern naturalists are known to have become absolutely extinct, though there are some cases in which they are ascertained to have utterly disappeared from the face of the earth in very recent times. The most familiar instances are those of the dodo, a large bird peculiar to the Mauritius or Isle of France, exterminated about the year 1690, and now known only by two or three fragments of skeletons, and the solitary, which inhabited the islands of Bourbon and Rodriguez, but has not been seen for more than a century. A parrot and some other birds of the Norfolk Island group are said to have lately become extinct. The wingless auk, *Alca impennis*, a bird remarkable for its excessive fatness, was very abundant two or three hundred years ago in the Faroe Islands, and on the whole Scandinavian sea-board. The early voyagers found either the same or a closely allied species, in immense numbers, on all the coasts and islands of Newfoundland. The value of its flesh and its oil made it one of the most important resources of the inhabitants of those sterile regions, and it was

naturally an object of keen pursuit. It is supposed to be now completely extinct, and few museums can show even its skeleton.

There seems to be strong reason to believe that our boasted modern civilization is guiltless of one or two sins of extermination which have been committed in recent ages. New Zealand formerly possessed three species of dinornis, one of which, called *moa* by the islanders, was much larger than the ostrich. The condition in which the bones of these birds have been found, and the traditions of the natives concur to prove that, though the aborigines had probably extirpated them before the discovery of New Zealand by the whites, they still existed at a comparatively late period. The same remarks apply to a winged giant the eggs of which have been brought from Madagascar. This bird must have much exceeded the dimensions of the *moa*; at least so far as we can judge from the egg, which is eight times as large as the average size of the ostrich egg, or about one hundred and fifty times that of the hen.

But though we have no evidence that man has exterminated many species of birds, we know that his persecutions have caused their disappearance from many localities where they once were common, and greatly diminished their numbers in others. The cappercailzie, *Tetrao urogallus*, the finest of the grouse family, formerly abundant in Scotland, had become extinct in Great Britain, but has been reintroduced from Sweden. The ostrich is mentioned by all the old travellers, as common on the Isthmus of Suez down to the middle of the seventeenth century.

It appears to have frequented Syria and even Asia Minor at earlier periods, but is now found only in the seclusion of remoter deserts.

The modern increased facilities of transportation have brought distant markets within reach of the

professional hunter, and thereby given a new impulse to his destructive propensities. Not only do all Great Britain and Ireland contribute to the supply of game for the British capital, but the canvas-back duck of the Potomac, and even the prairie hen from the basin of the Mississippi, may be found at the stalls of the London poulterer. Kohl informs us that on the coasts of the North Sea, twenty thousand wild ducks are usually taken in the course of the season in a single decoy, and sent to the large maritime towns for sale. The statistics of the great European cities show a prodigious consumption of game birds but the official returns fall far below the truth, because they do not include the rural districts, and because neither the poacher nor his customers report the number of his victims. Reproduction, in cultivated countries, cannot keep pace with this excessive destruction, and there is no doubt that all the wild birds which are chased for their flesh or their plumage are diminishing with a rapidity which justifies the fear that the last of them will soon follow the dodo and the wingless auk.

Fortunately, the larger birds which are pursued for their flesh or for their feathers, and those the eggs of which are used as food, are, so far as we know the functions appointed to them by nature, not otherwise specially useful to man, and, therefore, their wholesale destruction is an economical evil only in the same sense in which all waste of productive capital is an evil. If it were possible to confine the consumption of game fowl to a number equal to the annual increase, the world would be a gainer, but not to the same extent as it would be by checking the wanton sacrifice of millions of the smaller birds, which are of no real value as food, but which, as we have seen, render a most important service by battling, in our behalf, as well as in their own, against the countless legions of humming and of

creeping things, with which the prolific powers of insect life would otherwise cover the earth.

## The Habitable Earth Originally Wooded.

There is good reason to believe that the surface of the habitable earth, in all the climates and regions which have been the abodes of dense and civilized populations, was, with a few exceptions, already covered with a forest growth when it first became the home of man. This we infer from the extensive vegetable remains—trunks, branches, roots, fruits, seeds, and leaves of trees—so often found in conjunction with works of primative art, in the boggy soil of districts where no forests appear to have existed within the eras through which written annals reach; from ancient historical records, which prove that large provinces, where the earth has long been wholly bare of trees, were clothed with vast and almost unbroken woods when first made known to Greek and Roman civilization; and from the state of much of North and of South America when they were discovered and colonized by the European race.

These evidences are strengthened by observation of the natural economy of our own time; for, whenever a tract of country, once inhabited and cultivated by man, is abandoned by him and by domestic animals,* and surrendered to the undisturbed in-

* Browsing animals, and most of all the goat, are considered by foresters as more injurious to the growth of young trees, and, therefore, to the reproduction of the forest than almost any other destructive cause. "According to Beatson's Saint Helena, introductory chapter, and Darwin's Journal of Researches in Geology and Natural History, pp. 582, 583," says, Ewsmann in the notes to his translation of Foissac, p. 654, "it was the goats which destroyed the beautiful forests that, three hundred and fifty years ago, covered a continuous surface of not less than two thousand acres in the interior of the island of (St. Helena), not to mention scattered groups of trees. Darwin observes: During our stay at Valparaiso, I was most positively assured that sandal wood formerly grew in abundance on the island of Juan Fernandez, but that

fluences of spontaneous nature, its soil sooner or later clothes itself with herbaceous and arborescent plants, and at no long interval, with a dense forest growth. Indeed, upon surfaces of a certain stability, and not absolutely precipitous inclination the special conditions required for the spontaneous propagation of trees may all be negatively expressed and reduced to these three: exemption from defect or excess of moisture, from perpetual frost and from the depredations of man and browsing quadrupeds. Where these requisites are secured, the hardest rock is as certain to be overgrown with wood as the most fertile plain, though, for obvious reasons, the process is slower in the former than in the latter case. Lichens and mosses first prepare the way for a more highly organized vegetation. They retain the moisture of rains and dews, and bring it to act in combination with the gases evolved by their organic processes, in decomposing the surface of the rocks they cover; they arrest and confine the dust which the wind scatters over them, and their

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this tree had now became entirely extinct there, having been extirpated by the goats which early navigators had introduced. The neighbouring islands, to which goats have not been carried, still abound in sandal wood."

I am convinced that forests would soon cover many parts of the Arabian and African deserts, if man and domestic animals, especially the goat and the camel, were banished from them. The hard palate and tongue and strong teeth and jaws of this latter quadruped enable him to break off and masticate tough and thorny branches as large as the finger. He is particularly fond of the smaller twigs, leaves and seedpods of the Sout and other acacias, which like the American Robinia, thrive well on dry and sandy soils, and he spares no tree, the branches of which are within his reach, except, if I remember right, the tamarisk that produces manna. Young trees sprout plentifully around the springs, and along the winter water-courses of the desert, and these are just the halting stations of the caravans and their routes of travel. In the shade of these trees, annual grasses and perennial shrubs shoot up, but are mown down by the hungry cattle of the Bedouin, as fast as they grow. A few years of undisturbed vegetation would suffice to cover such points with groves and these would gradually extend themselves over soils where now scarcely any green thing but the bitter colocynth and the poisonous foxglove is ever seen.

final decay adds new material to the soil already half formed beneath and upon them. A very thin stratum of mould is sufficient for the germination of seeds of the hardy evergreens and birches, the roots of which are often found in immediate contact with the rock, supplying their trees with nourishment from a soil derived from the decomposition of their own foliage, or sending out long rootlets into the surrounding earth in search of juices to feed them.

### THE FOREST AS A SHELTER FROM WIND.

Experience has shown that mere rows of trees and even much lower obstructions are of essential service in defending vegetation against the action of the wind. Hardy proposes planting, in Algeria, belts of trees at the distance of one hundred métres from each other, as a shelter which experience had proved to be useful in France.* "In the valley of the Rhone," says Becquerel, "a simple hedge, two métres in height, is a sufficient protection for a distance of twenty-two métres."† The mechanical shelter acts, no doubt, chiefly as a defence against the mechanical force of the wind, but its uses are by no means limited to this effect. If the current of air which it resists moves horizontally, it would prevent the access of cold or parching blasts to the ground for a great distance; and did the wind even descend at a large angle with the surface, still a considerable extent of ground would be protected by a forest to the windward of it. If we suppose the trees of a wood to have a mean height of only twenty yards, they would often beneficially affect the temperature or the moisture of a belt of land two or three hundred yards in width, and thus perhaps rescue valuable crops from destruction.‡

* Becquerel, Des Climats, etc., p. 179. † Ibid, p. 116.

‡ The following well-attested instance of a local change of climate is probably to be referred to the influence of the forest as a shelter

Dussard, as quoted by Ribbe, maintains that even the mistral, or north-west wind, whose chilling blasts are so fatal to tender vegetation in the spring, "is "the child of man, the result of his devastations," "Under the reign of Augustus" continues he, the "forests which protected the Cevennes were felled, or destroyed by fire, in mass. A vast country, before covered with impenetrable woods—powerful obstacles to the movement and even to the formation of hurricanes—was suddenly denuded, swept bare, stripped, and soon after, a scourge hitherto unknown struck terror over the land from Avignon to the Bouches du Rhone, thence to Marseilles, and then extended its ravages, diminished indeed by a long career which had partly exhausted its force, over the whole maritime frontier. The people, thought this wind a curse sent of God. They raised altars to it and offered sacrifices to appease its rage." It

against cold winds. To supply the extraordinary demand for Italian iron occasioned by the exclusion of English iron in the time of Napoleon I., the furnaces of the valleys of Bergams were stimulated to great activity. "The ordinary production of charcoal not sufficing to feed the furnaces and the forges, the woods were felled, the copses cut before their time, and the whole economy of the forest was deranged. At Piazzatarre there was such a devastation of the woods, and consequently such an increased severity of climate, that maize no longer ripened. An association formed for the purpose, effected the restoration of the forest, and maize flourishes again in the fields of Piazzatarre."—Report by G. Rosa, in Il Politecnics, Dicembre, 1841, p. 614.

Similar ameliorations have been produced by plantations in Belgium. In an interesting series of articles by Bande, entitled "Les Cotes de la Manche," in the Revue des Deux Maudes, I find this statement: "A spectator, placed on the famous bell tower of the Cathedral of Antwerp, saw not long since, on the opposite side of the Schelde only a vast desert plain; now he sees a forest, the limits of which are confounded with the horizon. Let him enter within its shade. The supposed forest is but a system of regular rows of trees, the oldest of which is not forty years of age. These plantations have ameliorated the climate which had doomed to sterility, the soil where they are planted. While the tempest is violently agitating their tops, the air a little below is still, and sands far more barren than the plateau of La Hague have been transformed, under their protection, into fertile fields"—Revue des Deux Maudes, January 1859, p. 277.

seems however, that this plague was less destructive than at present, until the close of the sixteenth century, when further clearings had removed most of the remaining barriers to its course. Up to that time, the north-west wind appears not to have attained to the maximum of specific effect which now characterizes it as a local phenomenon. Extensive districts from which the rigor of the seasons has now banished valuable crops, were not then exposed to the loss of their harvests by tempests, cold or drought. The deterioration was rapid in its progress. Under the Consulate, the clearings had exerted so injurious an effect upon the climate, that the cultivation of the olive had retreated several leagues; and since the winters and springs of 1820 and 1836, this branch of rural industry has been abandoned in a great number of localities where it was advantageously pursued before. The orange now flourishes only at a few sheltered points of the coast, and it is threatened even at Hyéres, where the clearing of the hills near the town has proved very prejudicial to this valuable tree. • • •

## Total Influence of the Forest on Temperature.

It has not yet been found practicable to measure, sum up, and equate the total influence of the forest, its processes and its products, dead and living, upon temperature, and investigators differ much in their conclusions on this subject. It seems probable that in every particular case the result is, if not determined, at least so much modified by local conditions which are infinitely varied, that no general formula is applicable to the question.

Gay Lussac says: "In my opinion we have not yet any positive proof that the forest has, in itself, any real influence on the climate of a great country, or of a particular locality. By closely examining the effects of clearing off the woods, we should per-

haps" find that, far from being an evil, it is an advantage; but these questions are so complicated when they are examined in a climatological point of view, that the solution of them is very difficult, not to say impossible. Becquerel, on the other hand, considers it certain that in tropical climates, the destruction of the forests is accompanied with an elevation of the mean temperature, and he thinks it highly probable that it has the same effect in the temperate zones. The following is the substance of his remarks on this subject:—

"Forests act as frigorific causes in three ways:

"1. They shelter the ground against solar irradiation and maintain a greater humidity.

"2. They produce a cutaneous transpiration by the leaves.

"3. They multiply, by the expansion of their branches, the surfaces which are cooled by radiation."

These three causes acting with greater or less force, we must, in the study of the climatology of a country, take into account the proportion between the area of the forests and the surface which is bared of trees and covered with herbs and grasses.

We should be inclined to believe *á prióri*, according to the foregoing considerations, that the clearing of the woods by raising the temperature and increasing the dryness of the air, ought to react on climate. There is no doubt that, if the vast desert of the Sahara were to become wooded in the course of ages, the sands would cease to be heated as much as at the present epoch, when the mean temperature is twenty-nine degrees [centigrade = 85° Fahr.]. In that case the ascending currents of warm air would

cease, or be less warm, and would not contribute by descending in our latitudes, to soften the climate of Western Europe. Thus the clearing of a great country may react on the climates of regions more or less remote from it. The observations by Boussingault leave no doubt on this point. This writer determined the mean temperature of wooded and of cleared points, under the same latitude and at the same elevation above the sea, in localities comprised between the eleventh degree of north and the fifth degree of south latitude, that is to say, in the portion of the tropics nearest to the equator, and where radiation tends powerfully during the night to lower the temperature under a sky without clouds.*

The result of these observations, which has been pretty generally adopted by physicists, is that the

* Becquerel. Des Climats, etc., pp.—141.

Dr. Williams made some observations on this subject in 1789 and in 1791, but they generally belonged to the warmer months and I do not know that any extensive series of comparisons between the temperature of the ground in the woods and the fields has been attempted in America.

Dr. William's thermometer was sunk to the depth of 19 inches and gave the following results :—

| Time. | | Temperature of ground in pasture. | Temperature of ground in woods. | Difference. |
|---|---|---|---|---|
| May ... ... | 23 | 52 | 46 | 6 |
| " ... ... | 28 | 57 | 48 | 9 |
| June ... ... | 15 | 64 | 51 | 13 |
| " ... ... | 27 | 62 | 51 | 11 |
| July ... ... | 16 | 62 | 51 | 11 |
| " ... ... | 30 | 65½ | 55½ | 10 |
| August ... ... | 15 | 68 | 58 | 10 |
| " ... ... | 31 | 59½ | 55 | 4½ |
| September ... | 15 | 59½ | 55 | 4½ |
| October ... ... | 1 | 59½ | 55 | 4½ |
| " ... ... | 15 | 49 | 49 | 0 |
| November ... | 1 | 43 | 43 | 0 |
| " ... ... | 16 | 43½ | 43½ | 0 |

mean temperature of cleared land in the tropics appears to be about one degree centigrade, or a little less than two degrees of Fahrenheit, above that of the forest.

## Influence of Forests on the Humidity of the Air and the Earth.

The most important influence of the forest on climate is no doubt, that which it exercises on the humidity of the air and the earth, and this climatic action it exerts partly as dead, partly as living matter. By its interposition as a curtain between the sky and the ground, it intercepts a large proportion of the dew and the lighter showers, which would otherwise moisten the surface of the soil, and restores it to the atmosphere by evaporation; while in the heavier rains, the large drops which fall upon the leaves and branches are broken into smaller ones, and consequently strike the ground with less mechanical force, or are perhaps even dispersed into vapor without reaching it. As a screen it prevents the access of the sun's rays to the earth, and of course, an elevation of temperature which would occasion a great increase of evaporation. As a mechanical obstruction, it impedes the passage of air currents over the ground, which, as is well known, is one of the most efficient agents in promoting evaporation and the refrigeration resulting from it. In the forest the air is almost quiescent, and moves only as local changes of temperature affect the specific gravity of its particles. Hence there is often a dead calm in the woods when a furious blast is raging in the open country at a few yards' distance. The denser the forest—as for example, where it consists of spike-leaved trees, or is thickly intermixed with them—the more obvious is its effect, and no one can have passed from the field to the wood in cold, windy weather, without having remarked it.

The vegetable mould, resulting from the decomposition of leaves and of wood, carpets the ground with a spongy covering which obstructs the evaporation from the mineral earth below, drinks up the rains and melting snows that would otherwise flow rapidly over the surface and perhaps be conveyed to the distant sea, and then slowly gives out by evaporation, infiltration and percolation, the moisture thus imbibed. The roots too, penetrate far below the superficial soil, conduct the water along their surface to the lower depths to which they reach, and thus serve to drain the superior strata and remove the moisture out of the reach of evaporation.

In the primitive forest the surface of the ground is so much encumbered, (often indeed half covered) with trunks and branches of fallen trees that there sometimes seems to be as much wood prostrate as growing, and the necessity of climbing over or creeping under the over-turned trees is the greatest difficulty in forest travelling. These decayed or wind-fallen trees intercept much of the water of precipitation, and convert the face of the earth almost, sometimes altogether, into a bog. (See Milton and Headle's Travels.) The settler, for convenience, especially for cutting roads and paths, drags out the trunks and uses them for firewood or other purposes, thereby at the same time partially draining the wood. A few years suffice to get rid of much of this material, and the wood, though still native and self-propagating, soon acquires to some extent the character of an artificial forest. This process was gone through long ago in most European countries, so that there is scarcely any truly virgin forest left in Central or Western Europe in the condition in which nature would have placed it. An experienced eye at once recognizes a modern wood as, in part at least, man's work. Especially is this the case in Tyrol and the other Southern Austrian provinces

occupied, as existing architectural remains still show, and at least partly cleared, hundreds if not thousands of years ago. Several successive crops of forest trees have since grown, but always under Governmental supervision. The valley of the Drave, for instance, had anciently large towns, and of course adjacent fields, but the country is now almost completely wooded, and it is only since the opening of the rail road through the Pusterthal and thence to Austrian and Italian markets, that these new forests have been a little broken. Many inroads have now been made upon them for the sake of the timber, and slides and torrents have already begun their ravages. But not only do these forests differ from spontaneous native woods in their general physiognomy, but the individual trees have changed their habits. Among the conifers, not only the larch but firs show a change in ramification, sending up shoots from the roots as well as laterally, and otherwise approximating in growth to deciduous trees.

INFLUENCE OF THE FOREST ON PRECIPITATION.

I believe that a majority of the foresters and physicists who have studied the question are of opinion that in many, if not in all cases, the destruction of the woods has been followed by a diminution in the annual quantity of rain and dew. Indeed, it has long been a popularly settled belief that vegetation and the condensation and fall of atmospheric moisture are reciprocally necessary to each other, and even the poets sing of

> Africs barren sand,
> Where nought can grow, because it raineth not,
> And where no rain can fall to bless the land,
> Because nought grows there.

Beginning with the latest authorities, I cite a passage from Clané. After arguing that we cannot reason from the climatic effects of the forest in tropical

and sub-tropical countries as to its influence in temperate latitudes, the author proceeds: "The action of the forests on rain, a consequence of that which they exercise on temperature, is difficult to estimate in our climate, but is very pronounced in hot countries, and is established by numerous examples. M. Baussingault states that in the region comprised between the Bay of Cupica and the Gulf of Guayaquil which is covered with immense forests, the rains are almost continual, and that the mean temperature of this humid country rises hardly to twenty-six degrees (= 80° Fah.) M. Blanqui, in his 'Travels in Bulgaria,' informs us that at Malta rain has become so rare, since the woods were cleared to make room for the growth of cotton, that at the time of his visit in October, 1841, not a drop of rain had fallen for three years. The terrible droughts which desolate the Cape Verde Islands must also be attributed to the destruction of the Forests. In the Island of St. Helena, where the wooded surface has considerably extended within a few years, it has been observed that the rain has increased in the same proportion. It is now in quantity double what it was during the residence of Napoleon. In Egypt, recent plantations have caused rains, which hitherto were almost unknown."

Schacht observes: "In wooded countries, the atmosphere is generally humid, and rain and dew fertilize the soil. As the lightning rod abstracts the electric fluid from the stormy sky, so the forest attracts to itself the rain from the clouds which, in falling, refreshes not it alone, but extends its benefits to the neighbouring fields. The forest presenting a considerable surface for evaporation, gives to its own soil and to all the adjacent ground an abundant and enlivening dew. There falls, it is true, less dew on a tall and thick wood than on the surrounding meadows, which, being more highly heated

during the day by the influence of insolation, cool with greater rapidity by radiation. But it must be remarked, that this increased deposition of dew on the neighbouring fields is partly due to the forests themselves; for the dense, saturated strata of air which hover over the woods descend in cool, calm evenings, like clouds, to the valley, and in the morning, beads of dew sparkle on the leaves of the grass and the flowers of the field. Forests, in a word, exert in the interior of Continents, an influence like that of the sea on the climate of islands and of coasts; they water the soil and thereby insure its fertility."

In a number of the Missionary Herald published at Boston, the date of which I have mislaid, the Rev. Mr. Van Lennep, well known as a competent observer gives the following remarkable account of a similar fact witnessed by him in an excursion to the east of Tocat in Asia Minor:

In this region some 3,000 feet above the sea, the trees are mostly oak, and attain a large size. I noticed an illustration of the influence of trees in general in collecting moisture. Despite the fog, of a week's duration, the ground was everywhere perfectly dry. The dry oak leaves, however, had gathered the water and the branches and trunks of the trees were more or less wet. In many cases the water had run down the trunk and moistened the soil around the roots of the tree. In two places, several trees had each furnished a small stream of water, and these, uniting, had run upon the road, so that travellers had to pass through the mud; although as I said everywhere else the ground was perfectly dry. Moreover the collected moisture was not sufficient to drop directly from the leaves, but in every case it ran down the branches and trunk to the ground. Further on we found a grove, and at the foot of each tree, on the north side, was a lump

of ice, the water having frozen as it reached the ground. This is a most striking illustration of the acknowledged influence of trees in collecting moisture; and one cannot for a moment, doubt that the parched regions which commence at Sivas and extend in one direction to the Persian Gulf, and in another to the Red Sea, were once a fertile garden, teeming with a prosperous population, before the forests which covered the hill-sides were cut down—before the cedar and the fir-tree were rooted up from the sides of Lebanon.

Coultas thus argues: "The ocean, winds, and woods may be regarded as the several parts of a grand distillatory apparatus. The sea is the boiler in which vapor is raised by the solar heat, the winds are the guiding tubes which carry the vapor with them to the forests, where a lower temperature prevails. This naturally condenses the vapor and showers of rain are thus distilled from the cloud masses which float in the atmosphere by the woods beneath them."

Sir John F. W. Herschel enumerates among "the influences unfavorable to rain," absence of vegetation in warm climates, and especially of trees. "This is, no doubt" continues he, "one of the reasons of the extreme aridity of Spain. The hatred of a Spaniard toward a tree is proverbial. Many districts in France have been materially injured by denudation and, on the other hand, rain has become more frequent in Egypt since the more vigorous cultivation of the palm tree."

Hohenstein remarks: "With respect to temperature in the forest I have already observed that at certain times of the day and of the year, it is less than in the open field, Hence the woods may, in the day-time, in summer and toward the end of winter, tend to increase the fall of rain; but it is

otherwise in summer nights and at the beginning of winter when there is a higher temperature in the forest, which is not favorable to that effect. The wood is, further, like the mountain a mechanical obstruction to the motion of rain clouds, and, as it checks them in their course, it gives them occasion to deposit their water. These considerations render it probable that the forest increases the quantity of rain; but they do not establish the certainty of this conclusion, because we have no positive numerical data to produce on the depression of temperature, and the humidity of the air in the woods."

Barth presents the following view of the subject: "The ground in the forest, as well as the atmospheric stratum over it, continues humid after the woodless districts have lost their moisture; and the air, charged with the humidity drawn from them, is usually carried away by the winds before it has deposited itself in a condensed form on the earth. Trees constantly transpire through their leaves a great quantity of moisture, which they partly absorb again by the same organs, while the greatest part of their supply is pumped up through their widely ramifying roots from considerable depths in the ground. Thus a constant evaporation is produced, which keeps the forest atmosphere moist even in long droughts when all other sources of humidity in the forest itself are dried up.

Little is required to compel the stratum of air resting upon a wood to give up its moisture, which thus, as rain, fog, or dew, is returned to the forest. The warm, moist currents of air which came from other regions are cooled as they approach the wood by its less heated atmosphere, and obliged to let fall the humidity with which they are charged. The woods contribute to the same effect by mechanically impeding the motion of fog and rain cloud, whose particles are thus accumulated and condensed to rain. The

forest thus has a greater power than the open ground to retain within its own limits already existing humidity, and to preserve it, and it attracts and collects that which the wind brings it from elsewhere, and forces it to deposit itself as rain or other precipitation. In consequence of these relations of the forest to humidity, it follows that wooded districts have both more frequent and more abundant rain, and in general are more humid, than woodless regions; for what is true of the woods themselves, in this respect, is true also of their treeless neighbourhood, which in consequence of the ready mobility of the air and its constant changes, receive a share of the characteristics of the forest atmosphere, coolness and moisture. When the districts stripped of trees have long been deprived of rain and dew, and the grass and the fruits of the field are ready to wither, the grounds which are surrounded by woods are green and flourishing. By night they are refreshed with dew, which is never wanting in the moist air of the forest, and in due season they are watered by a beneficent shower or a mist which rolls slowly over them.

Ashjarnsen, after adducing the familiar theoretical arguments on this point, adds: "The rainless territory in Peru and North Africa establish this conclusion, and numerous other examples show that woods exert an influence in producing rain, and that rain fails where they are wanting; for many countries have, by the destruction of the forests, been deprived of rain moisture, springs, and water-courses, which are necessary for vegetable growth. The narratives of travellers show the deplorable consequences of felling the woods in the Island of Trinidad, Martinique, San Domingo, and indeed in almost the entire West Indian group. In Palestine and many other parts of Asia and Northern Africa, which in ancient times where the granaries of Europe, fertile

and populous, similar consequences have been experienced. These lands are now deserts, and it is the destruction of the forests alone which has produced this desolation. In Southern France many districts have, from the same cause, become barren wastes of stone, and the cultivation of the vine and the olive has suffered severely since the baring of the neighbouring mountains. Since the extensive clearings between the Spree and the Oder, the inhabitants complain that the clover crop is much less productive than before. On the other hand, examples of the beneficial influence of planting and restoring the woods are not wanting. In Scotland, where many miles square have been planted with trees, this effect has been manifest, and similar observations have been made in several places in Southern France. In lower Egypt, both at Cairo, and near Alexandria, rain rarely fell in considerable quantity —for example during the French occupation of Egypt, about 1798, it did not rain for sixteen months—but since Mehemet Ali and Ibrahim Pacha, executed their vast plantations (the former alone having planted more than twenty millions of olive and fig trees, cottonwood, oranges, acacias, planes, &c.,) there now falls a good deal of rain, especially along the coast, in the months of November, December, and January; and even at Cairo it rains both oftener and more abundantly, so that real showers are no rarity."

Babinet, in one of his lectures, cites the supposed fact of the increase of rain in Egypt in consequence of the planting of trees, and thus remarks upon it, "A few years ago it never rained in lower Egypt. The constant north winds, which almost exclusively prevail there, passed without obstruction over a surface bare of vegetation. Grain was kept on the roofs in Alexandria, without being covered or otherwise protected from injury, by the atmosphere; but

since the making of plantations, an obstacle has been created which retards the current of air from the north. The air thus checked, accumulates, dilates, cools and yields rain. The forests of the Vosges and Ardennes produce the same effects in the north-east of France, and send us a great river, the Meuse, which is as remarkable for its volume as for the small extent of its basin. With respect to the retardation of the atmospheric currents, and the effects of that retardation, one of my illustrious colleagues, M. Mignet, who is not less a profound thinker than an eloquent writer, suggested to me that, to produce rain, a forest was as good as a mountain, and this is literally true." Manesteir Savignat arrives at this conclusion: "Forests on the one hand diminish evaporation; on the other they act on the atmosphere as refrigerating causes. The second scale of the balance predominates over the other, for it is established that in wooded countries it rains oftener, and that the quantity of rain being equal, they are more humid."

Baussingault whose observations on the drying up of lakes and springs, from the destruction of the woods in tropical America, have often been cited as a conclusive proof that the quantity of rain was thereby diminished—after examining the question with much care, remarks: "In my judgment it is settled that very large clearings must diminish the annual fall of rain in a country;" and on a subsequent page he concludes that, "Arguing from meteorological facts collected in the equinoctial regions, there is reason to presume that clearings diminish the annual fall of rain."

The effect of the forest on precipitation is not entirely free from doubt, and we cannot positively affirm that the total annual quantity of rain is diminished or increased by the destruction of the woods, though both theoretical considerations and the

balance of testimony strongly favor the opinion, that more rain falls in wooded than in open countries. One important conclusion at least, upon the meteorological influence of forest is certain and undisputed : the proposition, namely, that within their own limits, and near their own borders, they maintain a more uniform degree of humidity in the atmosphere than is observed in cleared grounds. Scarcely less can it be questioned that they promote the frequency of showers, and, if they do not augment the amount of precipitation, they equalize its distribution through the different seasons.

The experience of observing persons confirms the popular saying: "All signs fail in dry times." This is partly an expression of the law of probabilities according to which, the longer a particular *spell* of weather as continued, the greater are the chances that it will continue yet longer; but there is a physical reason why, after a long drought, appearances, which, under ordinary circumstances, would almost certainly indicate an approaching rainstorm, prove delusive. It is this: after a drought of some days, which generally occurs only after a protracted continuance of hot weather, the surface of the ground is not only dry but heated, and, like any other heated body, throws off heat into the atmosphere. This heat tends to make the air capable of containing more humidity, and the vapor held in the atmosphere over an extent of heated ground, and which might otherwise be precipitated and form rain, is dissipated and carried off. Thus the clouds that gather round mountain peaks are seen to vanish as they pass over the plains below. The forest does not become heated by the sun, and therefore does not radiate heat enough to dissolve the vapor in the atmosphere above it, while the open ground, being warmed by the sun, radiates heat into the air which drifts over it.

The *lowest* limit of perpetual snow is said to be from 2,000 to 4,000 feet lower on the Southern than on the Northern slope of the Himalayas. The explanation of this apparently anomalous fact is found partly in the condensation and congelation of the moisture with which the Southern monsoon is charged, and its precipitation as snow on the Southern scarp of this mighty chain. But the configuration of the earth's surface in this region furnishes another explanation to which some physical geographers ascribe even greater importance. This lofty chain is skirted on the north by the extensive, high plateau of Thibet which is without forests, and it has been believed that the naked surface of this plateau emits, by reflection and radiation, heat enough to dissolve the moisture of the atmospheric strata above it, and thus to prevent the formation of rains and of snows. Our vast Western fields and plains, though lower by ten thousand feet, must exercise a similar function and probably materially modify the amount of precipitation in our climate. Whether the Russian steppes exert a like influence is a question to which, as far as I know, attention has not yet been directed.

## Absorption of Moisture from Ground and Atmosphere by Trees.

These are the principal modes in which the humidity of the atmosphere is affected by the forest regarded as lifeless matter. Let us inquire how its organic processes act upon this meteorological element.

The commonest observation shows that the wood and bark of living trees are always more or less pervaded with watery, and other fluids, one of which, the sap, is very abundant in trees of deciduous foliage when the buds begin to swell and the leaves to develop themselves in the spring. The outer bark of most trees is of a corky character, not admitting

the absorption of much moisture from the atmosphere through its pores, and we can hardly suppose that the buds are able to extract from the air a much larger supply. The obvious conclusion as to the source from which the extraordinary quantity of sap at this season is derived, is that to which scientific investigation leads us, namely, that it is absorbed from the earth by the roots and thence distributed to all parts of the plant. Popular opinion, indeed, supposes that all the vegetable fluids, during the entire period of growth, are thus drawn from the bosom of the earth, and that the wood and other products of the tree are wholly formed from matter held in solution in the water abstracted by the roots from the ground. This is an error, for, not only is the solid matter of the tree, in a certain proportion not important to our present inquiry, received from the atmosphere in a gaseous form, through the pores of the leaves and of the young shoots, but water in the state of vapor is absorbed and contributed to the circulation by the same organs. The amount of water taken up by the roots, however, is vastly greater than that imbibed through the leaves, especially at the season when the juices are most abundant, and when we have seen, the leaves are yet in embryo. The quantity of water thus received from the air and the earth, in a single year, by a wood of even of a hundred acres is very great, though experiments are wanting to furnish the data for even an approximate estimate of its measure; for only the vaguest conclusions can be drawn from the observations which have been made on the imbibition and exhalation of water by trees and other plants reared in artificial conditions diverse from those of the natural forest.

The amount of sap which can be withdrawn from living trees furnishes, not indeed a measure of the quantity of water sucked up by their roots from the

ground—for we cannot extract from a tree its whole moisture—but numerical data which may aid the imagination to form a general notion of the powerful action of the forest as an absorbent of humidity from the earth.

The only forest tree known to Europe and North America, the sap of which is largely enough applied to economical uses to have made the amount of its flow a matter of practical importance and popular observation, is the sugar maple, Acer Saccharinum, of the Anglo-American Provinces and States. In the course of a single "sugar season," which lasts ordinarily from twenty-five to thirty days, a sugar maple two feet in diameter will yield not less than twenty gallons of sap, and sometimes much more. This, however, is but a trifling proportion of the water abstracted from the earth by the roots during this season when the yet-undeveloped leaves can hardly absorb an appreciable quantity of vapor from the atmosphere; for all this fluid runs from two or three incisions or auger holes, so narrow as to intercept the current of comparatively few sap vessels, and besides, experience shows that large as is the quantity withdrawn from the circulation, it is relatively too small to affect very sensibly the growth of the tree. The number of large maple trees on an acre is frequently not less than fifty, and of course the quantity of moisture abstracted from the soil by this tree alone is measured by thousands of gallons to the acre. The sugar orchards, as they are called, contain also many young maples too small for tapping, and numerous other trees—two of which, at least, the black birch, betula lenta, and yellow birch, betula excelsa, both very common in the same climate, are far more abundant in sap than the maple—are scattered among the sugar trees; for the North American native forests are remarkable for the mixture of their crops. The sap of the maple and of

other trees with deciduous leaves which grow in the same climate, flows most freely in the early spring, and especially in clear weather, when the nights are frosty and the days warm; for it is then that the melting snow supply the earth with moisture in the justest proportion and that the absorbent power of the roots is stimulated to its highest activity.

When the buds are ready to burst, and the green leaves begin to show themselves beneath their scaly covering, the ground has become drier, the thirst of the roots is quenched, and the flow of sap from them to the stem is greatly diminished. The leaves now commence the process of absorption, and imbibe both uncombined gases and an unascertained but perhaps considerable quantity of watery vapor from the humid atmosphere of spring which bathes them.

## Restoration to Atmosphere of a large proportion of Moisture absorbed.

The organic action of the tree, as thus far described, tends to the desiccation of air and earth; but when we consider what volumes of water are daily absorbed by a large tree and how small a proportion of the weight of this fluid consists of matter which enters into new combinations, and becomes a part of the solid frame work of the vegetable, or a component of its deciduous products, it is evident that the superfluous moisture must somehow be carried off almost as rapidly as it flows into the tree. At the very commencement of vegetation in spring, some of this fluid certainly escapes through the buds, the nascent foliage, and the pores of the bark and vegetable physiology tells us that there is a current of sap towards the roots as well as from them. I do not know that the exudation of water into the earth, through the bark or at the extremities of these latter organs, has been directly proved, but the other known

modes of carrying off the surplus do not seem adequate to dispose of it at the almost leafless period when it is most abundantly received, and it is therefore difficult to believe that the roots do not, to some extent, drain as well as flood the water-courses of their stem. Later in the season the roots absorb less, and the now developed leaves exhale a vastly increased quantity of moisture into the air. In any event all the water derived by the growing tree from the atmosphere and the ground is returned again by transpiration or exudation, after having surrendered to the plant the small proportion of matter required for vegetable growth which it held in solution or suspension. The hygrometrical equilibrium is then restored, so far as this, the tree yields up again the moisture it had drawn from the earth and the air, though it does not return it each to each; for the vapor carried off by transpiration greatly exceeds the quantity of water absorbed by the foliage from the atmosphere, and the amount, if any, carried back to the ground by the roots. The evaporation of the juices of the plants by whatever process effected, takes up atmospheric heat and produces refrigeration. This effect is not less real, though much less sensible, in the forest than in the meadow or pasture land and it cannot be doubted that the local temperature is considerably affected by it. But the evaporation that cools the air diffuses through it, at the same time, a medium which powerfully resists the escape of heat from the earth by radiation. Visible vapors or clouds, it is well known, prevent frosts by obstructing radiation, or rather by reflecting back again the heat radiated by the earth, just as any mechanical screen would do. On the other hand, clouds intercept the rays of the sun also, and hinder its heat from reaching the earth. The invisible vapors given out by leaves impede the passage of heat reflected and radiated by the earth and by all

terrestrial objects, but oppose much less resistance to the transmission of direct solar heat, and indeed the beams of the sun seem more scorching when received through clear air charged with uncondensed moisture than after passing through a dry atmosphere. Hence the reduction of temperature by the evaporation of moisture from vegetation, though sensible, is less than it would be if water in the gaseous state were as impervious to heat given out by the sun as to that emitted by terrestrial objects. The hygroscopicity of vegetable mould is much greater than that of any mineral earth, and therefore the soil of the forest absorbs more atmospheric moisture than the open ground. The condensation of the vapor by absorption disengages heat, and consequently raises the temperature of the soil which absorbs it. Von Babo found the temperature of sandy earth thus elevated from 20° to 27° centigrade making a difference of nearly thirteen degrees of Fahrenheit, and that of soil rich in humus from 20° to 31° centigrade a difference of almost twenty degrees of Fahrenneit.

## General Functions of Forests.

In the preceding pages we have seen that the electrical and chemical action of the forest, though obscure, exercises probably a beneficial, certainly not an injurious, influence on the composition and condition of the atmosphere; that it serves as a protection against the diffusion of miasmatic exhalations and malarious poisons; that it performs a most important function as a mechanical shelter from blasting winds to grounds and crops in the lee of it; that as a conductor of heat, it tends to equalize the temperature of the earth and the air; that its dead products form a mantle over the surface which protects the earth from excessive heat and cold; that the evaporation from the leaves of

living trees, while it cools the air around them, diffuses through the atmosphere a medium which resists the escape of warmth from the earth by radiation, and hence that its general effect is to equilibrate caloric influences and moderate extremes of temperature.

We have seen further, that the forest is equally useful as a regulator of terrestrial and of atmospheric humidity, preventing by its shade the drying up of the surface by parching winds and the scorching rays of the sun; intercepting a part of the precipitation and pouring out a vast quantity of aqueous vapor into the atmosphere; that if it does not increase the amount of rain, it tends to equalize its distribution both in time and in place; that it preserves a hygrometric equilibrium in the superior strata of the earth's surface; that it maintains and regulates the flow of springs and rivulets; that it checks the superficial discharge of the waters of precipitation and consequently tends to prevent the sudden rise of rivers, the violence of floods, the formation of destructive torrents, and the abrasion of the surface by the action of running water; that it impedes the fall of avalanches and of rocks and destructive slides of the superficial strata of mountains; that it is a safeguard against the breeding of locusts, and finally that it furnishes nutriment and shelter to many tribes of animal and of vegetable life which, if not necessary to man's existence, are conducive to his rational enjoyment. In fine, in well-wooded regions, and in inhabited countries where a due proportion of soil is devoted to the growth of judiciously distributed forests, natural destructive tendencies of all sorts are arrested or compensated and man, bird, beast, fish, and vegetable alike find a constant uniformity of condition most favorable to the regular and harmonious co-existence of them all.

## General Consequences of the Destruction of the Forest.

With the extirpation of the forest, all is changed. At one season, the earth parts with its warmth by radiation to an open sky—receives, at another, an immoderate heat from the unobstructed rays of the sun. Hence the climate becomes excessive, and the soil is alternately parched by the fervors of summer, and seared by the rigors of winter. Bleak winds sweep unresisted over its surface, drift away the snow that sheltered it from the frost, and dry up its scanty moisture. The precipitation becomes as irregular as the temperature; the melting snows and vernal rains, no longer absorbed by a loose and bibulous vegetable mould, rush over the frozen surface, and pour down the valleys seawards, instead of filling a retentive bed of absorbent earth and storing up a supply of moisture to feed perennial springs. The soil is bared of its covering of leaves, broken and loosened by the plough, deprived of the fibrous rootlets which held it together, dried and pulverized by sun and wind and at last exhausted by new combinations. The face of the earth is no longer a sponge, but a dust-heap, and the floods which the waters of the sky pour over it hurry swiftly along its slopes, carrying in suspension vast quantities of earthy particles which increase the abrading power and mechanical force of the current, and augmented by the sand and gravel of falling banks, fill the beds of the streams, divert them into new channels, and obstruct their outlets. The rivulets, wanting their former regularity of supply and deprived of the protecting shade of the woods, are heated, evaporated, and thus reduced in their summer currents, but swollen to raging torrents in autumn and in spring. From these causes there is a constant degradation of the uplands, and a consequent elevation of the beds of water-courses and of lakes by the deposition of the

mineral and vegetable matter carried down by the waters. The channels of great rivers become unnavigable, their estuaries are choked up, and harbours which once sheltered large navies are shoaled by dangerous sandbars. The earth stripped of its vegetable glebe, grows less and less productive, and consequently less able to protect itself by weaving a new network of roots to bind its particles together, a new carpeting of turf to shield it from wind and sun and scouring rain. Gradually it becomes altogether barren. The washing of the soil from the mountain leaves bare ridges of sterile rock, and the rich organic mould which covered them, now swept down into the dark low grounds, promotes a luxuriance of aquatic vegetation that breeds fever, and more insidious forms of mortal disease by its decay, and thus the earth is rendered no longer fit for the habitation of man.

To the general truth of this sad picture there are many exceptions, even in countries of excessive climates. Some of these are due to favorable condition of surface, of geological structure, and of the distribution of rain; in many others, the evil consequences of man's improvidence have not yet been experienced, only because a sufficient time has not elapsed since the felling of the forest, to allow them to develop themselves. But the vengeance of nature for the violation of her harmonies, though slow, is sure, and the gradual deterioration of soil and climate in such exceptional regions is as certain to result from the destruction of the woods as is any natural effect to follow its cause.

## Due Proportion of Woodland.

The proportion of woodland that ought to be permanently maintained for its geographical and atmospheric influences varies according to the character of soil, surface and climate. In countries with a humid

sky, or moderately undulating surface and an equable temperature, a small extent of forest, enough to serve as a mechanical screen against the action of the wind in localities where such protection is needed, suffices. But most of the territory occupied by civilized man is exposed, by the character of its surface and its climate, to a physical degradation which cannot be averted except by devoting a large amount of soil to the growth of the woods.

From an economical point of view, the question of the due proportion of forest is not less complicated or less important than in its purely physical aspects. Of all the raw materials which nature supplies for elaboration by human art, wood is undoubtedly the most useful, and at the same time the most indispensable to social progress.

The demand for wood, and of course the quantity of forest required to furnish it, depend upon the supply of fuel from other sources, such as peat and coal, upon the extent to which stone, brick, or metal can advantageously be substituted for wood in building, upon the development of arts and industries employing wood and other forest products as materials, and upon the cost of obtaining them from other countries, or upon their commercial value as articles of export.

Upon the whole, taking civilized Europe and America together, it is probable that from twenty to twenty-five per cent. of well wooded surface is indispensable for the maintenance of normal physical conditions, and for the supply of materials so essential to every branch of human industry and every form of social life as those which compose the harvest of the woods.

There is probably no country—there are few large farms even—where at least one-fourth of the soil is not either unfit for agricultural use, or so unproductive that, as pasture or as plough land, it yields less

pecuniary return than a thrifty wood. Every prairie has its sloughs where willows and poplars would find a fitting soil, every Eastern farm its rocky nooks and its barren hill sides suited to the growth of some species from our rich forest flora, and everywhere belts of trees might advantageously be planted along the road sides and the boundaries and dividing fences. In most cases it will be found that trees may be made to grow well where cultivated crops will not repay the outlay of tillage and it is a very plain dictate of sound economy that if trees produce a better profit than the same ground would return if devoted to grass or grain, the wood should be substituted for the field.

## Woodland in European Countries.

In 1862, Reutzsch calculated the proportions of woodland in different European countries as follows :—

| | | |
|---|---|---|
| Norway | 66 | per cent. |
| Sweden | 60 | ,, ,, |
| Russia | 30·90 | ,, ,, |
| Germany | 26·58 | ,, ,, |
| Belgium | 18·52 | ,, ,, |
| France | 16·79 | ,, ,, |
| Switzerland | 15· | ,, ,, |
| Sardinia | 12·29 | ,, ,, |
| Neapolitan States | 9·43 | ,, ,, |
| Holland | 7·10 | ,, ,, |
| Spain | 5·52 | ,, ,, |
| Denmark | 5·50 | ,, ,, |
| Great Britain | 5·00 | ,, ,, |
| Portugal | 4·40 | ,, ,, |

The large proportion of woodland in Norway and Sweden is in a great measure to be ascribed to the mountainous character of the surface which renders the construction of roads difficult and expensive, and hence the forests are comparatively inaccessible, and transportation is too costly to tempt the inhabitants to sacrifice their woods for the sake of supplying distant markets.

The industries which employ wood as a material have only lately been much developed in these countries, and though the climate requires the consumption of much wood as a fuel, the population is not numerous enough to create for this purpose a demand exceeding the annually produced supply, or to need any great extension of cleared ground for agricultural purposes. Besides this in many places peat is generally employed as domestic fuel Hence, though Norway has long exported a considerable quantity of lumber, and the iron and copper works of Sweden consume charcoal very largely, the forests have not diminished rapidly enough to produce very sensible climatic or even economical evils.

At the opposite end of the scale we find Holland, Denmark, Great Britain, Spain and Portugal. In the three first named countries a cold and humid climate renders the almost constant maintenance of domestic fires a necessity, while in Great Britain especially the demand of the various industries which depend on wood as a material, or on mechanical power derived from heat, are very great. Coal and peat serve as a combustible instead of wood in them all, and England imports an immense quantity of timber from her foreign possessions. Fortunately the character of soil, surface and climate renders the forest of less importance as a geographical agent in these northern regions than in Spain and Portugal, where all physical conditions concur to make a large extent of forest an almost indispensable means of industrial progress and social advancement.

## Exclusion of Domestic Quadrupeds.

But probably the most important of all rules for the government of the forest, whether natural or artificial, is that which prescribes the absolute exclusion of all domestic quadrupeds, except swine, from every wood which is not destined to be cleared. No

growth of young trees is possible where horned cattle, sheep or goats, or even horses, are permitted to pasture at any season of the year, though they are doubtless most destructive when trees are in leaf.* These animals browse upon the terminable buds and the tender branches thereby stunting, if they do not kill, the young trees, and depriving them of all beauty and vigour of growth.

## Forest Fires.

The difficulty of protecting the woods against accidental or incendiary fires is one of the most discouraging circumstances attending the preservation of natural and the plantation of artificial forests. In the spontaneous wood the spread of fire is somewhat retarded by the general humidity of the soil and of the beds of leaves which cover it. But in long droughts the superficial layer of leaves and the dry fallen branches becoming as inflammable as tinder, and the fire spreads with fearful rapidity, until its further progress is arrested by want of material, or more

*Although the economy of the forest has received little attention in the United States, no lover of American nature can have failed to observe a marked difference between a native wood from which cattle are excluded and one where they are permitted to browse, a few seasons suffice for the total extirpation of the "under-brush" including the young trees on which alone the reproduction of the forest depends, and all the branches of those of larger growth which hang within reach of the cattle are stripped of their buds and leaves, and soon wither and fall off. These effects are observable at a great distance, and a wood pasture is recognised, almost as far as it can be seen, by the regularity with which its lower foliage terminates at what Ruskin somewhere calls the "cattle-line." This always runs parallel to the surface of the ground and is determined by the height to which domestic quadrupeds can reach to feed upon the leaves. In describing a visit to the grand-ducal farm of San Rossore near Pisa, where a large herd of camels is kept, Chateauvieux says: "In passing through a wood of evergreen oaks, I observed that all the twigs and foliage of the trees were clipped up to the height of about twelve feet above the ground, without leaving a single spray below that level. I was informed that the browsing of the camels had trimmed the trees as high as they could reach." Lullin de Chateauvieux Lettres sur l'Italie, p. 113.

rarely, by heavy rains, sometimes caused, as many meteorologists suppose, by the conflagration itself.

In the artificial forest the annual removal of fallen or half-dried timber and the leaves and other droppings of the wood, though otherwise a very injurious practice, much diminishes the rapid spread of fires; and the absence of combustible underwood and the greater distance between the trees are additional safeguards. But on the other hand, the comparative dryness of the soil, and of any leaves or twigs which may remain upon it, and the greater facility for the passage of wind-currents through a regularly planted and more open wood, are circumstances unfavourable to the security of the trees against this formidable danger. The natural forest, unless isolated and of small extent, can be protected from fire only by a vigilance too costly to be systematically practised. But the artificial wood may be secured by a network of ditches and of paths or occasional open glades, which both check the running of the fire and furnish the means of approaching and combating it.

The experience of 1871 ought not to be wholly without value as a lesson. It is not possible to estimate the damage by forest fires in that disastrous year, in what were lately the north-western States and in Canada, but as the demand for lumber, and consequently, its market price, are rising at a rate higher than the interest on capital, in a geometrical ratio, one may almost say it is probable that ten years hence those fires will be thought to have diminished the national wealth by a larger amount than even the terrible conflagration at Chicago.

There is no good reason why Insurance Companies should not guarantee the proprietor of a wood as well as the owner of a house against damage by fire. In Europe there is no conceivable liability to pecuniary loss which may not be insured

against. The American Companies might at first be embarrassed in estimating the risk, but the experience of a few years would suggest safe principles, and all parties would find advantage in this extension of security.

### Destructive action of Torrents.

But the great, the irreparable, the appalling mischiefs which have already resulted, and threaten to ensue on a still more extensive scale hereafter from too rapid superficial drainage, are of a properly geographical character, and consist primarily in erosion, displacement, and transportation of the superficial strata, vegetable and mineral of the integuments, so to speak, with which nature has clothed the skeleton framework of the globe. It is difficult to convey by description an idea of the desolation of the regions most exposed to the ravages of torrent and of flood; and the thousands, who in these days of travel, are whirled by steam near or even through the theatres of these calamities, have but rare aud imperfect opportunities of observing the destructive causes in action. Still more rarely can they compare the fact with the actual condition of the provinces in question and trace the progress of their conversion from forest crowned hills, luxuriant pasture grounds, and abundant corn fields and vineyards well watered by springs and fertilizing rivulets, to bald mountain ridges, rocky declivities, and steep earth banks furrowed by deep ravines with beds now dry, now filled by torrents of fluid mud and gravels hurrying down to spread themselves over the plain, and dooming to everlasting barrenness the once productive fields. In traversing such scenes, it is difficult to resist the impression that nature pronounced the curse of perpetual sterility and desolation upon these sublime but fearful wastes, difficult to believe that they were once, and but for the folly of man might still be, blessed with

all the natural advantages which Providence has bestowed upon the most favored climes. But the historical evidence is conclusive as to the destructive changes occasioned by the agency of man upon the flanks of the Alps, the Apennines, the Pyrenees and other mountain ranges in Central and Southern Europe, and the progress of physical deterioration has been so rapid that in some localities, a single generation has witnessed the beginning and the end of the melancholy revolution.

It is certain that a desolation, like that which has overwhelmed many once beautiful and fertile regions of Europe, awaits an important part of the territory of the United States and of other comparatively new countries over which European civilization is now extending its sway, unless prompt measures are taken to check the action of destructive causes already in operation.

## Torrents in France.

I have stated in a general way, the nature of the evils in question, and of the processes by which they are produced, but I shall make their precise character and magnitude better understood by presenting some descriptive and statistical details of facts of actual occurrence. I select for this purpose the south-eastern portion of France, not because that territory has suffered more severely than some others, but because its deterioration is comparatively recent and has been watched and described by very competent and trustworthy observers, whose reports are more easily accessible than those published in other countries.

* * * *

The eminent political economist Blanqui, in a memoir read before the Academy of Moral and Political Science on the 25th of November 1843, thus expresses himself: "Important as are the causes of

impoverishment already described, they are not to be compared to the consequences which have followed from the two inveterate evils of the Alpine provinces of France, the extension of clearing and the ravages of torrents. * * The most important result of this destruction is this : that the agricultural capital, or rather the ground itself, which in a rapidly increasing degree is daily swept away by the waters —is totally lost. Signs of unparalleled destitution are visible in all the mountain zone, and the solitudes of those districts are assuming an indescribable character of sterility and desolation. The gradual destruction of the woods has in a thousand localities, annihilated at once the springs and the fuel. Between Grenoble and Briançon in the valley of the Romanche, many villages are so destitute of wood that they are reduced to the necessity of baking their bread with sun-dried cowdung, and even this they can afford to do but once a year. This bread becomes so hard that it can be cut only with an axe, and I have myself seen a loaf of bread in September, at the kneading of which I was present the January previous.

"Whoever has visited the valley of Barcelonette, those of Embrun, and of Verdun, and that Arabia Petræa of the department of the Upper Alps, called Dêvolny, knows that there is no time to lose, that in fifty years from this date France will be separated from Savoy, as Egypt from Syria, by a desert."

It deserves to be specially noticed that the district here referred to, though now among the most hopelessly waste in France, was very productive even down to so late a period as the commencement of the French Revolution. Arthur Young, writing in 1789 says: "About Barcelonette and in the highest parts of the mountains, the hill pastures feed a million of sheep, besides large herds of other cattle."

"I do not exaggerate," says Blanqui, "When I shall have finished my excursion and designated localities by their names, there will rise, I am sure, more than one voice from the spots themselves, to attest the rigorous exactness of this picture of their wretchedness. I have never seen its equal even in the Kabyle villages of the province of Constantine; for there you can travel on horseback, and you find grass in the spring, whereas in more than fifty communes in the Alps there is absolutely nothing.

The clear, brilliant, alpine sky of Embrun, of Gap, of Barcelonette, and of Dique, which for months is without a cloud, produces droughts interrupted only by diluvial rains like those of the Tropics. The abuse of the right of pasturage and the felling of the woods have stripped the soil of all its grass and all its trees, and the scorching sun bakes it to the consistence of prophyry. When moistened by the rain, as it has neither support nor cohesion, it rolls down to the valleys sometimes in floods resembling black yellow or reddish lava, sometimes in streams of pebbles, and even huge blocks of stone which pour down with a frightful roar, and in their swift course exhibit the most convulsive movements. If you overlook from an eminence one of these landscapes furrowed with so many ravines it presents only images of desolation and of death. Vast deposits of flinty pebbles, many feet in thickness which have rolled down and spread far over the plain, surround large trees, bury even their tops, and rise above them, leaving to the husbandman no longer a ray of hope. One can imagine no sadder spectacle than the deep fissures in the flanks of the mountains which seem to have burst forth in eruption to cover the plains with their ruins. These gorges under the influence of the sun which cracks and shivers to fragments the very rocks, and of the rain which sweeps them down, penetrate deeper and deeper into

the heart of the mountain, while the beds of the torrents issuing from them are sometimes raised several feet in a single year, by the debris, so that they reach the level of the bridges, which of course are then carried off. The torrent beds are recognised at a great distance, as they issue from the mountains and they spread themselves over the low grounds in fan-shaped expansions, like a mantle of stone, sometimes ten thousand feet wide, rising high at the centre, and curving toward the circumference, till their lower edges meet the plain.

* * * *

"The unfortunate passion for clearing manifested itself at the beginning of the French Revolution, and has much increased under the pressure of immediate want. It has now reached an extreme point, and must be speedily checked, or the last inhabitant will be compelled to retreat when the last tree falls.

"The elements of destruction are increasing in violence. Rivers might be mentioned whose beds have been raised ten feet in a single year. The devastation advances in geometrical progression as the higher slopes are bared of their wood, and 'the ruin from above,' to use the words of a peasant, 'helps to hasten the desolation below.'

"The Alps of Provence present a terrible aspect. In the more equable climate of Northern France, one can form no conception of those parched mountain gorges where not even a bush can be found to shelter a bird, where at most, the wanderer sees in summer here and there a withered lavender, where all the springs are dried up and where a dead silence, hardly broken by even the hum of an insect, prevails. But if a storm bursts forth, masses of water suddenly shoot from the mountain heights into the shattered gulfs, waste without irrigating, deluge without refreshing the soil they overflow in their swift descent,

and leave it even more seared than it was from want of moisture, man at last retires from the fearful desert, and I have the present season, found not a living soul in districts where I remember to have enjoyed hospitality thirty years ago."

In 1853, ten years after the date of Blanquis' memoir, M. deBonville, prefect of the Lower Alps, addressed to the Government a report in which the following passages occur:

"It is certain that the productive mould of the Alps, swept off by the increasing violence of that curse of the mountains, the torrents, is daily diminishing with fearful rapidity. All our Alps are wholly, or in large proportion, bared of wood. Their soil, scorched by the sun of Provence, cut up by the hoofs of the sheep, which not finding on the surface the grass they require for their sustenance, scratch the ground in search of roots to satisfy their hunger, is periodically washed and carried off by melting snows and summer storms."

* * * *

"An indirect proof of the diminution of the soil is to be found in the depopulation of the country. In 1852, I reported to the General Council that, according to the census of that year the population of the department of the Lower Alps had fallen off no less than 5,000 souls in the five years between 1846 and 1851.

Unless prompt and energetic measures are taken it is easy to fix the epoch when the French Alps will be but a desert. The interval between 1851 and 1856 will show a further decrease of population. In 1862 the ministry will announce a continued and progressive reduction in the number of acres devoted to agriculture; every year will aggravate the evil, and in a half century, France will count more ruins, and a department the less."

Time has verified the predictions of deBonville. The later census returns show a progressive diminution in the population of the departments of the Lower Alps, the Isére, the Drome, Ariége, the Upper and the Lower Pyrenees, the Lozére, the Ardennes, the Doubs, the Vosges, and in short in all the provinces formerly remarkable for their forests. This diminution is not to be ascribed to a passion for foreign emigration, as in Ireland and in parts of Germany and of Italy ; it is simply a transfer of population from one part of the Empire to another, from soils which human folly has rendered uninhabitable by ruthlessly depriving them of their natural advantages and securities, to provinces where the face of the earth was so formed by nature as to need no such safeguards, and where consequently, she preserves her outlines in spite of the wasteful improvidence of man.

## The Forest in Italy.

The denudation of the Central and Southern Apennines and of the Italian declivity of the Western Alps began at a period of unknown antiquity, but it does not seem to have been carried to a very dangerous length until the foreign conquests and extended commerce of Rome created a greatly increased demand for wood for the construction of ships and for military material. The Eastern Alps, the Western Apennines, and the Maritime Alps retained their forests much later ; but even here the want of wood, and the injury to the plains and the navigation of the rivers by sediment brought down by the torrents, led to some legislation for the protection of theforests by the Republic of Venice in the fifteenth century, by that of Genoa as early at.least as the seventeenth ; and Marschand states that the latter Government passed laws requiring the proprietors of mountain lands to replant the woods.

These however do not seem to have been effectually enforced.

It is very common in Italy to ascribe to the French occupation under the first Empire all the improvements, and all the abuses of recent times, according to the political sympathies of the individual; and the French are often said to have prostrated every forest which has disappeared within a century. But however this may be, no energetic system of repression or restoration was adopted by any of the Italian States after the downfall of the Empire, and the taxes on forest property in some of them were so burdensome that rural municipalities sometimes proposed to cede their common woods to the Government, without any other compensation than the remission of the taxes imposed on forest lands; under such circumstances woodlands would soon become disafforested, and where facilities of transportation and a good demand for timber have increased the inducements to fell it, as upon the borders of the Mediterranean, the destruction of the forest and all the evils which attend it, have gone on at a seriously alarming rate. It has even been calculated that four-tenths of the area of the Ligurian provinces have been washed away or rendered incapable of cultivation by the felling of the woods.

## The Forests of France.

Mirabeau estimated the forests of France in 1750 at seventeen millions of hectares (42,000,000 acres); in 1860 they were reduced to 8 millions (19,769,000 acres). This would be at the rate of 82,000 hectares (202,600 acres) per year. Troy, from whose valuable pamphlet, Etude sur le Reboisement des montagues, I take these statistical details, supposes that Mirabeau's statement may have been an extravagant one, but it still remains certain that the waste has been enormous; for it is known that, in some departments,

that of Ariége, for instance, clearing has gone on during the last half century at the rate of three thousand acres a year and in all parts of the Empire trees have been felled faster than they have grown. The total area of France excluding Savoy is about one hundred and thirty-one millions of acres. The extent of forest supposed by Mirabeau would be about thirty-two per cent. of the whole territory.* In a country and a climate where the conservative influences of the forest are so necessary as in France, trees must cover a large surface and be grouped in large masses, in order to discharge to the best advantage the various functions assigned to them by nature. The consumption of wood is rapidly increasing in that empire, and a large part of its territory is mountainous, sterile, and otherwise such in character or situation that it can be more profitably devoted to the growth of wood than to any agricultural use. Hence it is evident that the proportion of forest in 1750, taking even Mirabeau's large estimate was not very much too great for permanent maintenance, though doubtless the distribution was so unequal that it would have been sound policy to

* In the Recepte Véritable Palissy having expressed his indignation at the folly of men in destroying the woods, his interlocutor defends the policy of felling them, by citing the example of "divers bishops, cardinals, priors, abbots, monkeries, and chapters which by cutting their woods have made three profits," the sale of the timber, the rent of the ground, and the "good portion" they received of the grain grown by the peasants upon it. To this argument Palissy replies, "I cannot enough detest this thing and I call it not an error, but a curse and a calamity to all France; for when forests shall be cut, all arts shall cease, and they which practise them shall be driven out to eat grass with Nebuchadnezzar and the beasts of the field. I have divers times thought to set down in writing the arts which shall perish when there shall be no more wood; but when I had written down a great number, I did perceive that there could be no end of my writing and having diligently considered, I found there was not any which could be followed without wood." * * "And truly I could well allege to thee a thousand reasons, but it is so cheap a philosophy, that the very chamber wenches, if they do but think, may see that without wood it is not possible to exercise any manner of human art or cunning." Œuvres de Bernard Palissy, p. 89.

fell the woods and clear land in some provinces, while large forests should have been planted in others.*

The due proportion in France would considerably exceed that for the German States, because France has relatively more surface unfit for any growth but that of wood, because the form and geological character of her mountains expose her territory to much greater injury from torrents, and because at least her southern provinces are more frequently visited both by extreme drought and by deluging rains.

## IRRIGATION AND ITS CLIMATIC AND GEOGRAPHIC EFFECTS.

We know little of the history of the extinct civilizations which preceded the culture of the classic ages, and no nation has in modern times spontaneously emerged from barbarism, and created for itself the arts of social life. The improvements of the savage races whose history we can distinctly trace are borrowed and imitative, and our theories as to the origin and natural development of industrial art are conjectural. Of course, the relative antiquity of particular branches of human industry depends much upon the natural character of soil, climate, and spontaneous vegetable and animal life in different countries; and while the geographical influence of man would, under given circumstances, be exerted in one direction, it would, under different conditions, act in an opposite or a diverging line. I have given some reasons for thinking that in the climates to

* Since writing the above paragraph, I have found the view I have taken of this point confirmed by the careful investigations of Reutzsch, who estimates the proper proportion of woodland to entire surface at 23 per cent. for the interior of Germany, and supposes that near the coast, where the air is supplied with humidity by evaporation from the sea, it might safely be reduced to 20 per cent. See Reutzsch's very valuable prize essay, Der Wald in Haushalt der Natur and der Volkswirth schaft, Cap. viii.

which our attention has been chiefly directed, man's first interference with the natural arrangement and disposal of the waters was in the way of drainage of surface. But if we are to judge from existing remains alone, we should probably conclude that irrigation is older than drainage; for, in the regions regarded by general tradition as the cradle of the human race, we find traces of canals evidently constructed for the former purpose at a period long preceding the ages of which we have any written memorials. There are, in ancient Armenia, extensive districts which were already abandoned to desolation at the earliest historical epoch, but which, in a yet remoter antiquity, had been irrigated by a complicated and highly artificial system of canals, the lines of which can still be followed; and there are, in all the highlands where the sources of the Euphrates rise, in Persia, in Egypt, in India, and in China, works of this sort which must have been in existence before man had begun to record his own annals.

In warm countries, such as most of those just mentioned, the effects I have described as usually resulting from the clearing of the forests would very soon follow. In such climates, the rains are inclined to be periodical; they are also violent, and for these reasons the soil would be parched in summer and liable to wash in winter. In these countries, therefore, the necessity for irrigation must soon have been felt, and its introduction into mountainous regions like Armenia must have been immediately followed by a system of terracing, or at least scarping the hillsides. Pasture and meadow, indeed, may be irrigated even when the surface is both steep and irregular, as may be observed abundantly on the Swiss as well as on the Piedmontese slope of the Alps; but in dry climates, plough land and gardens on hilly grounds require terracing, both for support-

ing the soil and for administering water by irrigation, and it should be remembered that terracing, of itself, even without special arrangements for controlling the distribution of water, prevents or at least checks the flow of rain-water, and gives it time to sink into the ground instead of running off over the surface.

There are few things in continental husbandry which surprise English or American observers so much as the extent to which irrigation is employed in agriculture, and that, too, on soils, and with a temperature, where their own experience would have led them to suppose it would be injurious to vegetation rather than beneficial to it. The summers in Northern Italy, though longer, are very often not warmer than in New England; and in ordinary years, the summer rains are as frequent and as abundant in the former country as in the latter. Yet in Piedmont and Lombardy, irrigation is bestowed upon almost every crop, while in New England it is never employed at all in farming husbandry, or indeed for any purpose except in kitchen gardens, and possibly, in rare cases, in some other small branch of agricultural industry.

The summers in Egypt, in Syria, and in Asia Minor and even Rumelia, are almost rainless. In such climates the necessity of irrigation is obvious, and the loss of the ancient means of furnishing it readily explains the diminished fertility of most of the countries in question. The surface of Palestine, for example, is composed, in a great measure, of rounded limestone hills, once, no doubt, covered with forest. These were partially removed before the Jewish conquest. When the soil began to suffer from drought, reservoirs to retain the waters of winter were hewn in the rock near the tops of the hills, and the declivities were terraced. So long as the cisterns were in good order, and the terraces kept up, the fertility of Palestine was unsurpassed,

but when misgovernment and foreign and intestine war occasioned the neglect or destruction of these works—traces of which still meet the traveller's eye at every step,—when the reservoirs were broken and the terrace walls had fallen down, there was no longer water for irrigation in summer, the rains of winter soon washed away most of the thin layer of earth upon the rocks, and Palestine was reduced almost to the condition of a desert.

The course of events has been the same in Idumæa. The observing traveller discovers everywhere about Petra, particularly if he enters the city by the route of Wadi Ksheibeh, very extensive traces of ancient cultivation, and upon the neighbouring ridges are the ruins of numerous cisterns evidently constructed to furnish a supply of water for irrigation. In primitive ages, the precipitation of winter in these hilly countries was, in great part, retained for a time in the superficial soil, first by the vegetable mould of the forests, and then by the artificial arrangements I have described . The water imbibed by the earth was partly taken up by direct evaporation, partly absorbed by vegetation, and partly carried down by infiltration to subjacent strata which gave it out in springs at lower levels, and thus a fertility of soil and a condition of the atmosphere were maintained sufficient to admit of the dense population that once inhabited those now arid wastes. At present, the rain-water runs immediately off from the surface and is carried down to the sea, or is drunk up by the sands of the Wadis, and the hill sides which once teemed with plenty are bare of vegetation, and seared by the scorching winds of the desert.

In Southern Europe, in the Turkish Empire, and in many other countries, a very large proportion of the surface is, if not absolutely flooded, at least thoroughly moistened by irrigation, a great number of times in the course of every season, and this,

especially, at periods when it would otherwise be quite dry, and when, too, the power of the sun and the capacity of the air for absorbing moisture are greatest. Hence it is obvious that the amount of evaporation from the earth in these countries, and, of course, the humidity and the temperature of both the soil and the atmosphere in contact with it, must be much affected by the practice of irrigation. The cultivable area of Egypt, or the space accessible to cultivation, between desert and desert, is more than seven thousand square statute miles. Much of the surface, though not out of the reach of irrigation, lies too high to be economically watered, and irrigation and cultivation are therefore confined to an area of five or six thousand square miles, nearly the whole of which is regularly and constantly watered when not covered by the inundation, except in the short interval between the harvest and the rise of the waters. For nearly half of the year, then, irrigation adds five or six thousand square miles, or more than a square equatorial degree, to the evaporable surface of the Nile valley, or, in other words, more than decuples the area from which an appreciable quantity of moisture would otherwise be evaporated; for after the Nile has retired within its banks, its waters by no means cover one-tenth of the space just mentioned. The fresh water canals now constructing, in connection with the works for the Suez Canal, will not only restore the long abandoned fields east of the Nile, but add to the arable soil of Egypt hundreds of square miles of newly reclaimed desert, and thus still further increase the climatic effects of irrigation.

The Nile receives not a single tributary in its course through Egypt; there is not so much as one living spring in the whole land, and, with the exception of a narrow strip of coast, where the annual precipitation is said to amount to six inches, the fall of rain in the territory of the Pharaoh's is not two

inches in the year. The subsoil of the whole valley is pervaded with moisture by infiltration from the Nile, and water can everywhere be found at the depth of a few feet. Were irrigation suspended, and Egypt abandoned, as in that case it must be, to the operations of nature, there is no doubt that trees, the roots of which penetrate deeply, would in time establish themselves on the deserted soil, fill the valley with verdure, and perhaps at last temper the climate, and even call down abundant rain from the heavens. But the immediate effect of discontinuing irrigation would be, first, an immense reduction of the evaporation from the valley in the dry season, and then a greatly augmented dryness and heat of the atmosphere. Even the almost constant north wind—the strength of which would be increased in consequence of these changes—would little reduce the temperature of the narrow cleft between the burning mountains which hem in the channel of the Nile, so that a single year would transform the most fertile of the soils to the most barren of deserts, and render uninhabitable a territory that irrigation makes capable of sustaining as dense a population as has ever existed in any part of the world. Whether man found the valley of the Nile a forest, or such a waste as I have just described, we do not historically know. In either case, he has not simply converted a wilderness into a garden, but has unquestionably produced extensive climatic change.

The fields of Egypt are more regularly watered than those of any other country bordering on the Mediterranean, except the rice grounds in Italy, and perhaps the *marcite* or winter meadows of Lombardy; but irrigation is more or less employed throughout almost the entire basin of that sea, and is everywhere attended with effects which, if less in degree, are analogous in character to those resulting from it in Egypt. In general, it may be said that the soil is

nowhere artificially watered except when it is so dry that little moisture would be evaporated from it, and, consequently, every acre of irrigated ground is so much added to the evaporable surface of the country. When the supply of water is unlimited, it is allowed, after serving its purpose on one field, to run into drains, canals, or rivers. But in most regions where irrigation is regularly employed, it is necessary to economize the water; after passing over or through one parcel of ground, it is conducted to another; no more is withdrawn from the canals at any one point than is absorbed by the soil it irrigates, or evaporated from it, and, consequently, it is not restored to liquid circulation, except by infiltration or precipitation. We are safe, then, in saying that the humidity evaporated from any artificially watered soil is increased by a quantity bearing a large proportion to the whole amount distributed over it; for most even of that which is absorbed by the earth is immediately given out again either by vegetables or by evaporation.

It is not easy to ascertain precisely either the extent of surface thus watered, or the amount of water supplied, in any given country, because these quantities vary with the character of the season; but there are not many districts in Southern Europe where the management of the arrangements for irrigation is not one of the most important branches of agricultural labor. The eminent Engineer Lombardini describes the system of irrigation in Lombardy as "every day in summer, diffusing over 550,000 hectares of land 45,000,000 cubic metres of water, which is equal to the entire volume of the Seine at an ordinary flood, or a rise of three metres above the hydrometer at the bridge of La Tournelle at Paris." Niel states the quantity of land irrigated in the former kingdom of Sardinia, including Savoy, in 1856, at 240,000 hectares, or not much less than 600,000

acres. This is about four-thirteenths of the cultivable soil of the kingdom. According to the same author, the irrigated lands in France did not exceed 100,000 hectares, or 247,000 acres, while those in Lombardy amounted to 450,000 hectares, more than 1,100,000 acres. In these three States alone, then, there were more than three thousand square miles of artificially watered land, and if we add the irrigated soils of the rest of Italy, of the Mediterranean islands, of the Spanish Peninsula, of Turkey in Europe and in Asia Minor, of Syria, of Egypt and the remainder of Northern Africa, we shall see that irrigation increases the evaporable surface of the Mediterranean basin by a quantity bearing no inconsiderable proportion to the area naturally covered by water within it. As near as can be ascertained, the amount of water applied to irrigated lands is scarcely any where less than the total precipitation during the season of vegetable growth, and in general it much exceeds that quantity. In grass grounds and in field culture it ranges from 27 or 28 to 60 inches, while in smaller crops, tilled by hand labor, it is sometimes carried as high as 300 inches. The rice grounds and the *marcite* of Lombardy are not included in these estimates of the amount of water applied. Arrangements are concluded, and new plans proposed, for an immense increase of the lands fertilized by irrigation in France and Italy, and there is every reason to believe that the artificially watered soil of the latter country will be doubled, that of France quadrupled, before the end of this century. There can be no doubt that by these operations man is exercising a powerful influence on soil, on vegetable and animal life, and on climate, and hence that in this, as in many other fields of industry, he is truly a geographical agency.

The quantity of water artificially withdrawn from running streams for the purpose of irrigation is such

as very sensibly to affect their volume, and it is, therefore, an important element in the geography of rivers. Brooks of no trifling current are often wholly diverted from their natural channels to supply the canals, and their entire mass of water completely absorbed, so that it does not reach the river which it naturally feeds, except in such proportion as it is conveyed to it by infiltration. Irrigation, therefore, diminishes great rivers in warm countries by cutting off their sources of supply as well as by direct abstraction of water from their channels. We have just seen that the system of irrigation in Lombardy deprives the Po of a quantity of water equal to the total delivery of the Seine at ordinary flood, or, in other words, of the equivalent of a tributary navigable for hundreds of miles by vessels of considerable burden. The new canals commenced and projected will greatly increase the loss The water required for irrigation in Egypt is less than would be supposed from the exceeding rapidity of evaporation in that arid climate; for the soil is thoroughly saturated during the inundation, and infiltration from the Nile continues to supply a considerable amount of humidity in the dryest season. Linant Bey computed that twenty-nine cubic metres per day sufficed to irrigate a hectare in the Delta. This is equivalent to a fall of rain of two millimetres and nine-tenths per day, or, if we suppose water to be applied for one hundred and fifty days during the dry season, to a total precipitation of 435 millimetres, about seventeen inches and one-third. Taking the area of actually cultivated soil in Egypt at the low estimate of 3,600,000 acres, and the average amount of water daily applied in both Upper and Lower Egypt at twelve hundredths of an inch in depth, we have an abstraction of 61,000,000 cubic yards which—the mean daily delivery of the Nile being in round numbers 320,000,000 cubic yards—is nearly one-fifth of

the average quantity of water contributed to the Mediterranean by that river.

Irrigation, as employed for certain special purposes in Europe and America, is productive of very prejudicial climatic effects. I refer particularly to the cultivation of rice in the Slave States of the American Union and in Italy. The climate of the Southern States is not necessarily unhealthy for the white man, but he can scarcely sleep a single night in the vicinity of the rice grounds without being attached by a dangerous fever. The neighbourhood of the rice fields is less pestilential in Lombardy and Piedmont than in South Carolina and Georgia, but still very insalubrious to both man and beast. "Not only does the population decrease where rice is grown," says Escourron Milliago, "but even the flocks are attacked by typhus. In the rice grounds, the soil is divided into compartments rising in gradual succession to the level of the irrigating canal, in order that the water, after having flowed one field, may be drawn off to another, and thus a single current serve for several compartments, the lowest field, of course, still being higher than the ditch which at last drains both it and the adjacent soil. This arrangement gives a certain force of hydrostatic pressure to the water with which the rice is irrigated, and the infiltration from these fields is said to extend through neighbouring grounds sometimes to the distance of not less than a myriametre, or six English miles, and to be destructive to crops and even trees reached by it. Land thus affected can no longer be employed for any purpose but growing rice, and when prepared for that crop, it propagates still further the evils under which it had itself suffered, and, of course, the mischief is a growing one."

The attentive traveller in Egypt and Nubia cannot fail to notice many localities, generally of small extent, where the soil is rendered infertile by an ex-

cess of saline matter in its composition. In many cases, perhaps in all, these barren spots lie rather above the level usually flooded by the inundations of the Nile, and yet they exhibit traces of former cultivation. Recent observations in India, a notice of which I find in an account of a meeting of the Asiatic Society in the *Athenæum* of December 20, 1862, No. 1834, suggest a possible explanation of this fact. At this meeting, Professor Medlicott read an essay on "The saline efflorescence called 'Reh' and 'Kuller'," which is gradually invading many of the most fertile districts of Northern and Western India, and changing them into sterile deserts. It consists principally of sulphate of soda (Glauber's salts), with varying proportions of common salt. Mr. Medlicott pronounces "these salts (which, in small quantities are favorable to fertility of soil) to be the gradual result of concentration by evaporation of river and canal waters, which contain them in very minute quantities, and with which the lands are either irrigated or occasionally overflowed." The river inundations in hot countries usually take place but once in a year, and, though the banks remain submerged for days or even weeks, the water at that period, being derived principally from rains and snows, must be less highly charged with mineral matter than at lower stages, and besides, it is always in motion. The water of irrigation, on the other hand, is applied for many months in succession, it is drawn from rivers at the seasons when their proportion of salts is greatest, and it either sinks into the superficial soil, carrying with it the saline substances it holds in solution, or is evaporated from the surface, leaving them upon it. Hence irrigation must impart to the soil more salts than natural inundation. The sterilized grounds in Egypt and Nubia lying above the reach of the floods, as I have said, we may suppose them to have been first cultivated in that remote antiquity when the

Nile valley received its earliest inhabitants. They must have been artificially irrigated from the beginning; they may have been under cultivation many centuries before the soil at a lower level was invaded by man, and hence it is natural that they should be more strongly impregnated with saline matter than fields which are exposed every year, for some weeks, to the action of running water so nearly pure that it would be more likely to dissolve salts than to deposit them.

# FORESTS AND RAIN-FALL

## IN MADRAS.

Denudation of the country.

LET any one in the middle of the hot weather, say the month of May, in almost any part of the Madras Presidency climb to the top of one of the numerous rocky ridges which rise abruptly from the plains, and take a bird's-eye view of the surrounding country, or suppose that in the 20 districts comprising the Madras Presidency 10 persons in each district at equal distances, one from another were to do as described, and suppose after due inspection, the 200 people all met and gave an account of what they had seen, would it not in nine cases out of every ten be, a wide, bare plain, roasting in the heat of the sun, the earth everywhere exposed naked to its direct rays, except perhaps, where some small patch of green marks a tope, or a few scattered trees or hedges rather relieve the monotonous uniformity of the land with a few perpendicular lines, than afford any appreciable quantity of shade.

Rough method of ascertaining extent of denudation.

Insignificant area left.

A series of observations so made by intelligent observers would be quite worth while to have carried out, if any doubt remains in the mind of any one, as to what the result would be, and a carefully written description by each, of what the panorama before him revealed, would compile into an interesting and useful record.

There can however be no doubt of the result, which at any rate I shall assume to be as is above described, viz., that more than nine-tenths of the total area is bare of trees.

Former different state.

We have unquestionable historical evidence in Orme's History* of Hindustan and elsewhere as well as in the reports of early Collectors and the Revenue accounts, that a very different state of things existed in the early part of the century, when a quite considerable area, at least in some parts now bare, can be proved to have been more or less well wooded. Now it almost provokes a smile to use such a term as wooded, much less well wooded, in reference to any part of the plains in this Presidency. It is therefore of importance to get some definite notions of the effect of such a condition of things as now exists, as compared with what may not unreasonably be supposed to have been universal in the last century or earlier, viz., a well wooded country.

Question to be considered.

We are brought then to the question What are the effects of Forests;—And here we run the risk of entering upon thorny and difficult questions, much and often debated among scientific men of high eminence, without universally accepted conclusions on all points having been arrived at.

Undisputed facts and their effects.

Still we may, avoiding them, note down some of the effects of Forests about which all are agreed, and which the most scientific as well as the least instructed reader will readily concur to be self-evident. Thus, supposing that half of the total area of the Presidency was Forest or jungle covered in, say, the 10th century, and comparing that state of things with what we have assumed is the case now, we have to apply the following considerations.

(1.) Forest cools the general temperature by protecting the ground from the heat of the sun. Half the area of the Presidency was therefore cooler in the 10th century than it now is, and to this extent the total climate must have been less liable to extreme heat.

Cooling of temperature.

(2.) Forest prevents in several ways the rapid flowing off the soil of water in heavy rain, both by preventing the rain from reaching the ground directly, and by accumulating under the trees a mass of decayed leaves and vegetation which absorbs moisture like a sponge. Instead therefore of flowing rapidly off the bare fields into the streams, the rivers, and the sea, more of it soaks into the ground and keeps up the supply in springs and wells, and generally in the strata immediately below the surface.

Increased supply in springs.

We must suppose therefore that springs were more abundant, and wells more plentifully supplied with water and at less difficult levels in the 10th century than they are now.

(3.) Forests prevent the rapid evaporation of the rain after it has fallen. Compare an acre of ground soaked with heavy rain but exposed to a tropical sun with an equal area shaded by trees. In the 10th century I am, I think, at liberty to conclude that the fallen rain was less rapidly removed from half of the soil by evaporation than it now is, that a larger quantity from this cause remained to find its way lower down into the earth and as before to replenish the springs and wells.

Evaporation diminished.

(4.) Forests protect from, and break the force of the wind. The furious hot winds loaded with sand or dust are one of the annoyances of life in certain seasons now;—A fairly distributed proportion of half

Protection from wind.

the area of the country covered with woods, and there is no reason to suppose it was not fairly distributed, must have given the 10th century inhabitants of this Presidency no slight advantage in point of comfort by protection from hot winds.

Preservation of wild birds.

(5.) Forests supply safe retreats and building places for birds, as well as food when the crops are off the ground, and when insect life in the fields is either dead, or dormant out of reach. The birds thus protected prevent the plague of caterpillars and locusts, by which much damage is often caused in these days to the husbandman's crops. In the 10th century this source of loss, often of ruin, must have been absent, one natural difficulty the less to contend against.

Supply of timber and firewood.

(6.) Forests supply timber and firewood cheaply and abundantly. These are both scarce and dear now. The 10th century ryot had opportunities such as are now unknown of building substantial houses, farm buildings, etc., at small cost, the Rajahs and rich merchants their extensive residences or palaces. While there was then no reason for or object in depriving the land of the natural restorer of its fertility, the manure of the cattle. All arts dependent upon fire, as iron smelting, brick making, lime burning, pottery, glass manufacture, etc., must have had a chance such as in these days of prohibitive cost of fuel makes it no wonder that the palmy days (such as they were) of the Indian arts are gone by.

Improved cultivation.

(7.) A larger supply of water and of manure would again produce a better system of cultivation, and improved species of the crops cultivated ; if to this we

add the concentration of cultivating skill and labour upon the better lands of the country, we shall see additional reasons for thinking the 10th century inhabitant better off than we are.

Recapitulation.

Without then having once trenched upon any of the thorny questions which divide the scientific world we have arrived at a long series of advantages which a large proportion of forest covered land would beyond question secure. To recapitulate and amplify.

Recapitulation.

The perennial supply in streams and rivers would increase, and new springs and streams spring up when none exists now, the levels of wells be raised and their supply more abundant and continuous; high floods in rivers would be reduced, and less water wasted into the sea; tanks and channels not so much silted up by torrents following every heavy rain, carrying along sand and silt in great quantity; less danger to irrigation works, tanks, channels, etc., from sudden and violent floods; improvement of climate by cooling; safety of crops from locusts, caterpillars or other insects, due to preservation of small birds; improvement of cultivation by concentration of effort upon the best lands and by manure put to its proper use when firewood is abundant; multiplication of cattle in proportion to land cultivated by the large supply of fodder produced in properly kept jungles; ample and cheap supply of wood for building and other purposes; impetus to industrial arts and manufactures of all kinds the result of cheap fuel.

Field for improvement.

Will any one deny that this is a pretty long list of undisputed advantages possessed by a tropical country half covered with forests over one wholly or almost wholly denuded of them. And when it is added that not one-fourth of the whole area of the Madras

Presidency is in fact now under the plough, does there not seem a fair field for an improvement of all the conditions of life on a large scale by extensive re-forestation of the plains.

Application to a tropical country.

Be it always remembered that the point of the whole of the above argument rests upon the fact that we are dealing with a *tropical* and not a temperate climate. Great Britain half wood might be and probably would be anything but a pleasant place to live in, but India half wood would, as I think is above proved, certainly be a more agreeable abode from all possible points of view than it is at present.

Forest how to be obtained.

Granting then that a proportion of forest to bare or cultivated country varying from $\frac{1}{3}$ to $\frac{1}{2}$ would be an incalculable benefit to this country, the question comes, how is such a state of things to be obtained, especially when the condition of the finances and the many calls upon them in this country, are taken into consideration. The reply is, the question, what practical steps have to be taken, and what are they likely to cost. The first and by far the most important step is a simple and not expensive one, viz., the fencing of large areas and watching them in such a manner as to keep out cattle, goats, and other browsing animals and fire. This alone will secure the natural growth of scrub and low bushes at first, followed by occasional trees of the common kinds as the babool, the white thorn, etc., which in many places grow quite spontaneously if protected from animals. The process of fencing has upon I think sufficient reliable data been calculated to cost from Rs. 4 to Rs. 6 per acre, the blocks being of considerable size.

Fencing.

Keeping out domestic animals and fire.

Ploughing and sowing.

The next step is the ploughing of such fenced or protected areas with single furrows at intervals of 3 or 4 yards apart and sowing the ridges turned up with the seeds of such trees as are found to be indigenous to the district, and which may therefore be expected if sown in the rains to grow without watering and further care than protection from animals and the cultivator. This process carried on systematically and upon a large scale would be found to cost a very small sum per acre.

Preservation of land.

And these are the only two processes required to effect the required transformation, given besides time and the land. For the last lands now waste must be taken up and reserved for this purpose, the cultivator and his animals being kept out of them, and fenced, ploughed and sown by degrees as funds are available. These steps taken upon a carefully arranged system may fairly be expected to produce the most desirable result in a time proportioned to the funds available for expenditure upon it. Whenever money is available, five years should suffice to protect the ground fairly well from the sun, and it must depend therefore upon how many square miles of country there is money enough to deal with, how many years must be allowed for gaining the desired result.

A cheaper but still probably an effective plan will be to reserve on the whole, say twice as large an area as it is intended to make into real forest, a few prosecutions for trespass and impounding of cattle will suffice to prevent trespasser or cattle venturing beyond the outer edges of the area reserved and the inner portion that intended to be in future real forest may then be protected without the expense of fencing. All that would be wanted being a broad cleared boundary line round the whole beyond which

men and cattle would know they are trespassing, and a staff of forest guards, for the first year strong, but reduced every succeeding year as the people learn to respect the boundary.

Difficult questions.

I come now to the more or less thorny and disputed questions, as to which I do not profess to speak with the knowledge of a man of science, but regarding which I propose to put in as plain language as I can some of the principal facts or factors, upon which the solution of the problem appears to me to depend, and if I am allowed to draw my own conclusions, the reader will know that he may draw his too, and that he is not asked to consider my solution his, or correct unless he likes.

Quantity and distribution of rain-fall.

Here then comes the question do forests affect the *quantity* of rain-fall or its *distribution* and if so how. The subject is complicated and depends on many different factors, I propose to enumerate all I can, and to try to guage the effect of each separately, totalling up the separate effects at last. Various considerations must be put from which no conclusions are drawn, but upon which other considerations will be found to depend, upon which conclusions *are* drawn.

Hot and cold air in relation to moisture.

Air absorbs and retains moisture in proportion to its heat, more if hot less if cold.

Cooling of hot air.

The passage of air saturated, that is holding all it can hold of moisture, from a higher to a lower degree of heat must therefore cause it to give up a part of the moisture, since in its cooler state it cannot hold so much as in its hotter state, the result is familiar in the dew of a cool night, or in the fall of rain

from an atmosphere fully charged with moisture when cooled.

Moisture from the sea.

Almost all the moisture that comes to India comes from the surrounding seas by means first of evaporation, *i.e.*, saturation of the air over the sea, and 2nd of wind, *i.e.*, motion of the more or less saturated air, from its position over the sea to a position over the land.

Air always in motion.

Air is nearly always in motion but the rate of motion as well as the direction vary much.

Air motion constant in India.

Both the rate and the direction are pretty constant over India and the seas by which it is surrounded, and broadly speaking vary with the season of the year, or as we call them the monsoons.

Air motion constant in India.

It follows that the rate of motion and the direction of the more or less saturated air is nearly constant over seasons extending to several months at a time.

Degree of saturation of air.

Upon the rate of motion, and the breadth of the area of the sea or ocean over which the air has to pass before it reaches the land, must depend the degree of saturation it has attained by the time it reaches the land.

Degree of saturation of air.

Thus a wind coming from the Coast of Africa, across the Indian Ocean, and at a time of year when the sun is vertical or nearly so will, in all probability, be heavily charged or highly saturated with moisture. A wind in the opposite direction over the Bay of Bengal less so, but still heavily charged.

Vapor found in many forms and of very different weights.

Vapor of water is of many degrees of density, and of as many degrees of *weight*, but always as long as it is vapor lighter than air, when condensed into water it is heavier than air, and forms into rain and falls, or into dew and rests upon the ground.

Atmospheric power to support weight varies with altitude.

The atmosphere as a whole is, as shown by barometric observation, capable of supporting different amounts of weight at different elevations, most weight at sea level, and least in the highest ranges of the atmosphere above the tops of the loftiest mountains.

Vapor rests at different levels according to its weight.

Vapor of water accordingly rests in proportion to its degree of *weight* or density at different levels in the atmosphere, the lightest and least dense highest, the heaviest and most dense nearest to the surface of the earth.

Origin of clouds.

After the limit of the absorptive power of air is reached, evaporation still continuing over the sea, the air becomes supersaturated and holds more moisture than it can *absorb*, this excess it is that forms mist, fog, and clouds of all degrees of density, from the thinnest cirrus to the heaviest thunder cloud which the resisting power of air as measured by the barometric pressure near the earth's surface will sustain. Intermediate between the lightest and highest cirrus and the heavy low floating thunder cloud come the cirro stratus, the stratus, the cumulus, etc., at descending levels of the atmosphere.

These last four paragraphs contain considerations of great importance as will hereafter be seen; the reader is requested to note them carefully.

Action of clouds over sea.

Clouds so formed over the sea intercept the direct rays of the sun, which no longer strike the sea as before. The sea ceases to reflect these rays and the air above it begins to cool.

Rain at sea.

The resulting comparative cold condenses some of the moisture in the clouds or air and the result is rain. In this way rain at sea is dependent upon the cooling of the atmosphere by the interposition of clouds between the sun's rays and the sea. It is also caused by the coolness resulting from the absence of the sun during the night.

Saturated air and clouds pass from sea to land.

Turning now to the land it is clear that at different times air in motion will be carried from the sea across the land in different stages of saturation, and bearing a different amount of accumulated cloud moisture.

Limit of saturation.

It is also evident, that whatever air reaches the land must be in that degree of saturation at most that will not cause its discharge over the sea.

Condition required for rain to fall over land.

It follows that for such air to discharge rain over the land, a greater degree of coolness must result from some cause than exists at the time it left the sea over the sea, or that the rain must be due to other causes as well as condensation by coolness.

Heat and cold vary with latitude, tropical country only considered.

The causes of heat and cold and the resulting heat and cold on land vary with every latitude, and would require to be quite separately considered for temperate countries and for the tropics—taking only a tropical country.

Heat and cold in tropics where land bare.

Observation shows that bare land becomes hotter by day than sea and cooler at night, when the sun is at its lowest altitude during the cold season, but as the altitude of the sun increases the heat of the land and of the air above it accumulates until when the sun is vertical, the air over the land is both by night and by day hotter than it is on the sea.

Normal condition no rain in hot portion of year.

It is apparent then that at such seasons rain will not fall except under unusual circumstances.

Special circumstances cause exception.

Such special circumstances may be a counter current of wind, which by stopping the motion of the clouds causes them to bank and pile up one upon another until their absolute weight becomes greater than the barometric resistance of the air is able to support, and such cases would probably result in violent but local torrents of rain or thunder storms accompanied by a high barometer indicating the pressure of the weight of piled up cloud, and also very likely by violent wind the result of suddenly mingling airs of different densities temperatures and elastic pressures.

Special circumstances cause exception.

This cause of rain, viz., excessive weight of cloud beyond what the atmosphere can support is a quite distinct one from condensation by coolness, but is one of much importance; to it must be largely ascribed the effect of a mountain barrier upon advancing clouds in a stratum lower than its highest line. Since the cloud in such lower stratum being too heavy to rise over the barrier is arrested, fresh arrivals of cloud from the sea of the same stratum of air pile and bank up upon it, until the cloud mass becomes more than the air can

Effect of mountain barrier.

support and then follows a deluge of rain. This is what occurs at the burst of the South-west Moonsoon on the west side of the Ghâuts and largely accounts for their excessive rain-fall.

Monsoon on West Coast.

Conflicting currents of wind at least one of which is charged with clouds or vapor and is arrested or retarded in such a manner that the clouds further back in the air overtake and bank upon those arrested must be looked to as the frequent cause of local showers, and the well-known variability of the wind's direction in some countries and to a certain extent in all from local causes seems probably the cause of the proverbial uncertainty of showers or rain.

Conflicting currents of air and retardation of wind and clouds.

The careful study of wind and wind causes is therefore the first and chief step towards a knowledge of the times when we may expect rain. Thus the change of the wind from North-east to South-east at the close of the North-east Monsoon probably produces what are locally known as mango showers, and these again occur at the change from South-east to South-west at the commencement of the South-west Moonsoon wind. It is then not surprising that these showers occur at very regular times and are in their character sudden and heavy and of short duration.

Study of wind causes.

But to return to the normal conditions in the absence of mountain barriers and taking India and its surrounding seas and prevailing winds as they are at different seasons, and the facts of temperature as they are recorded from thermometer observations for the different seasons, and first the South-west Monsoon as most important.

India without mountains.

During.

The air is blown up from the sea either so load-

During. ed with moisture that it is on the point of discharging into the sea or less than this. Supposing there are no mountain barriers this more or less saturated air travels across the plain country in a North-east direction, and finds, supposing it to arrive at the end of May, a burnt up and bare country intensely heated by the sun in the day but rapidly radiating away the heat at night but on the whole an average much above that of the sea, and in consequence the air absorbs much of the moisture in the clouds and the remainder is vaporised into a lighter form of cloud and rises to a higher level.

Clouds driven up by heat.

But the South-west wind being produced by the heat of the plains of India gradually decreases in force as the more distant points of its origin are reached. The draw or suction being produced by every point in the plains that is exposed to the sun, the air on first arrival at the West Coast is subject to a North-easterly draw or suction from every point of the land, while 1,000 miles inland the draw from points it has passed and left behind no longer affects it, or if anything tends to retard, and it becomes a slower wind and the clouds travel slower. Those behind overtaking those in front, the masses increase in weight and density, the sun is obscured and the general temperature begins to fall; this produces a further cooling of the earth's surface and of the air above it, and this again a further condensation of cloud vapor, an increase of its weight and another descent of clouds to a lower stratum still of the atmosphere, this process continues until the point is reached at which even the lowest stratum of air which is capable of supporting the heaviest weight of vapor has more to carry than it can carry, and this combined

Retardation of wind over land.

Effect of retardation.

with increasing coolness produces rain. Observation also shows that the *rate* of the wind varies from day to day and week to week, in one place it is rapid in another slow, it must follow that the clouds when the rate is rapid overtake and coalesce with those where the rate is slow, the general direction as in the monsoon being the same throughout; besides then the general retardation of the whole monsoon wind, there will be numerous smaller local retardations often no doubt the cause of local showers or rains.

Effect of observed variability in wind velocity.

Thus we see that the action of the land heated by the sun is to drive up the clouds into the higher regions of the atmosphere, to absorb much of the moisture coming in from the sea, to make rain, other causes apart, impossible, and that the rain that does fall is due to other causes, the gradual cessation of wind, or the formation of contrary currents of wind which cause the banking up of cloud masses beyond the power of the air to sustain, or sufficient to cause a general cooling of the air at the earth's surface and so to condense the cloud moisture into rain.

General results.

Now suppose instead of a bare soil exposed to the heat of the sun and absorbing by day so much heat as to keep the nights also hotter than the nights on the sea, instead of this, suppose that we have the country wholly covered with forest. The earth is no longer kept heated and has little to give out at night to make up for the withdrawal of the sun's direct influence, the whole temperature is cooler, and the result, that the average temperature of the air on the land becomes less than that on the sea which is exposed to the sun's rays and accumulates heat in its waters and by reflection in the air above more than forest covered land can, though

India wholly covered with forest.

less than the bare earth does. The consequence is that the moisture coming in from the sea at once begins to be discharged, the clouds are at once relieved of part of their substance and pass relieved of some of their weight further inland, to be overtaken by similar clouds as the force of wind decreases and in the end to water the further areas with less violent downpours.

Release of latent heat.

An important factor here comes in, viz., the release of heat latent in vapor by its condensation. Directly the rain begins to fall this condensation produces heat, which increasing as the condensation proceeds, gradually gives back to the air its lost heat, and so puts a stop to the rain. If this were not so, the rain in the western portion of the country so wooded would be continuous as long as the South-west Monsoon lasts, but this natural factor works in counteraction to the coolness produced by trees, and by masses of clouds intercepting the sun, and the two counter agents working continually one against the other produce an oscillating partial equilibrium, so that at one time there is rain, and a little later the rain ceases and the moisture passes on into the interior.

Difference caused by absence or presence of forests.

On the whole comparing India denuded of forests with India covered with forests during the South-west Monsoon, the difference will be that in the first case rain only falls by virtue of the banking up of great cloud masses though the reduction of speed in wind as it reaches and passes the points of its origin, *i.e.*, as it travels North-eastwards, and by the obstruction of the direct heat of the sun by interfering banks and masses of cloud between it and the earth. In either case the tendency is to produce violent downpours of accumulated masses of cloud moisture, and when the

unevennesses of the ground surface, the rocky ranges and mountains scattered about over the plains also come into play we see that they naturally by offering a barrier to the advancing masses increase in particular localities this tendency, the masses pile up sooner and the downpour there becomes not only excessive when it comes but unevenly distributed, the level areas getting less and the hilly and rocky ridges more than their share. Violence and uneven distribution is then the character of the rain-fall in a country denuded of trees, and composed partly of wide plains and partly of ranges of hills or mountains when such a country is bare of forest.

Differences caused by absence or presence of forests.

On the other hand when uniformly forest covered the causes which produce rain-fall act at once, the clouds are at once relieved of a part of their burden by condensation the result of coolness, rather than of increase of weight due to piling up one on another beyond the power of the atmosphere to sustain. The coolness which produces this is gradually counteracted by the latent heat set free by the condensation, causing a break in the fall of rain, and allowing some of the moisture to travel on to water districts further off. Another factor, viz., coolness produced by forest shade comes into share with the physical obstructions resulting from the ranges of hills the effect of producing rain, and the latter is not so potent, both for that reason, and because the masses of vapor having been partially relieved from the first are not so heavy. The total result is that the rain is more constant, less violent, and less unevenly distributed.

A great distillery.

The whole circle of action has been aptly compared to a distillery on a grand scale in which the atmosphere is the boiler or retort, and the condensing apparatus is represented by forests, lakes, and whatever pro-

duces cold and condenses the vapor. The removal of the forests is thus equivalent to taking away the condenser from a distilling apparatus and the results similar.

Extreme cases indicate tendencies.

It is of course an extreme case to suppose the land entirely forest covered, but extreme cases indicate the tendency of causes and assuming the tendencies to be as above described, it appears clear that a fair proportion of only one-third of the total area of the country covered with forests *distributed with evenness* over the plains would have a tendency equal to one-third of the total tendency above described to produce the results which have been noted down, and there appears to be nothing in the present distribution of land among the cultivators to prevent as much as one-half the total area or even more being gradually covered with trees, some of it with fruit trees regularly cultivated, and the rest with forest trees or jungle or low scrub according to the nature of the soil, and be it always remembered that the poorest scrub has this great advantage over the finest and densest crop, that it does its duty in shading the ground through the hot weather, when cropped land is bare and roasting in a fierce sun, accumulating stores of heat destined to have a prejudicial effect upon the coming monsoon.

What actually takes place in the S.-W. Monsoon.

At the risk of repeating I will here note what appears to be the actual present succession of events at the South-west Monsoon. Air heavily saturated and masses of cloud as heavy as the air can support advance from the South-west. The lowest strata are at an elevation lower than the top of the Western Ghâuts. They strike upon these mountains and are not able to rise over them as the air at the top being more rarified and at a lower barometric pressure cannot

carry their weight, accordingly a large part of their moisture is discharged. Clouds in the same stratum keep on advancing behind them till the air of that stratum over the whole west coast country becomes charged with more than it can carry, and then the difference falls in rain and this process is continuous throughout the Monsoon, ceasing only when the latent heat given out by condensation of vapor is so great that it vaporises the heavy clouds and they rise into a higher stratum.

What actually takes place in the S.-W. Monsoon.

The higher strata above the level of the tops of the Ghâuts pass over and at once come into an atmosphere charged with all the heat of the hot weather in the plains. Large quantities of advancing clouds are absorbed into the dry hot air and disappear entirely, until the air has become saturated and can absorb no more, then the advancing stream of clouds begin to be seen making its way across the higher regions of the atmosphere above the plains towards the North-east.

What actually takes place in the S.-W. Monsoon.

As they advance, the rate of progression is reduced on the one hand, and on the other hand they interpose their own substance between the sun and the earth which gradually begins to cool down, and these two causes combining produce the massing of clouds and increase of their weight, and also the condensation of more into less vaporous cloud and in both cases a descent to lower ranges of atmosphere. Descending clouds then come in contact with lower ranges and ridges, pile up as before, and discharge torrents of rain, such piles or banks of clouds are also formed at different points by conflicting currents of air, and other more or less local causes, such for instance as the uneven level of the top of the Western Ghâuts, which in one

place allows to pass much more and lower cloud than at another. The general result being violent down-pours of rain in some places, and little rain in others.

Does forest effect quantity of rain-fall.

The last remaining question is, has the forest any effect upon the total *quantity* of the rain-fall, and we are now in a position to consider this by the light of the preceding considerations. We will compare India wholly denuded, with India wholly covered with forests, still in the South-west Monsoon season. We have seen that in the last case the comparative coolness produces rain, at once, on the arrival of the cloud masses and saturated air from the sea, while in the latter case rain does not fall except where clouds are stopped by mountain barriers, but passes over until by the decreasing speed of the wind and consequent piling up of masses of cloud advancing more rapidly from behind, and by the interposition of the clouds themselves between the earth and the sun producing greater coolness in the lower atmosphere the clouds are compelled to discharge.

The total quantity of rain discharged in the one or the other state of things depends upon several factors. First the length of time during which the saturated air and clouds are passing from the sea to the land being equal in both cases, *i.e.*, the Monsoon season or that during which the wind blows from the South-west, it follows, that the condition which favours this constant stream of cloud passing quite over India without discharge even for a comparatively small number of days at the beginning of the season, will unless compensated for by more complete discharge afterwards produce a diminished total fall, since perhaps 15 days of rain clouds have passed away to countries further east without discharge in one case, while in the other discharge has been going on from the first day. We have seen that the super-

heated condition of denuded land tends to have the effect of preventing the discharge from the clouds until they have accumulated to such an extent as to interpose a barrier between the sun and earth and the latter cools down. This means loss of time, out of the strictly limited months of the South-west Monsoon, and therefore other considerations apart, loss of rain-fall.

Again we have shown, and experience proves, that the clouds over bare plains are not constant even after they once form, but after one downpour they disappear, and the earth is again heated as before, the temporary withdrawal of the sun's heat producing but a temporary reduction of temperature, so that the gathering of cloud masses by the dropping of wind in front of their long file must be repeated over and over again with the intermission of spaces of time which practical observation shows to amount to weeks, between the times when the conditions are fulfilled for one and another downpour.

Does forest effect quantity of rain-fall.

All this time, in the forest clad country the discharging rain has not the radiation of sun from bare ground to contend with, but only the liberation of latent heat, and the rain will in consequence be much more frequent, and the intervals of dry weather less. The piling up due to retardation of the long array of clouds trooping up from the west, or to changing currents of air, is alike in both cases, only in the latter it causes less violent discharges, in proportion as the more continuous and frequent falls due to coolness, diminish the weight and amount of the passing cloud masses.

Does forest effect quantity of rain-fall.

Thus we have a distinctly considerable loss of time at the beginning of the Monsoon plus other considerable losses of time amounting in

fact to by much the greater portion of the whole number of days included in the Monsoon in the one case, to put against the more moderate discharges in the other.

Winds less violent effect of forests.

But there is again another factor not yet touched upon which must also come in. It is well-known that the South-west Monsoon wind is caused by the travelling of the air North-east which results from the heating of the plains of India itself, and of Southern Asia generally, causing the hot air to rise and the colder air from the sea to come in and take its place. The velocity and force of the wind will naturally be in proportion to the heat of the air, and in a country bare of trees will be greater than in one sheltered from the sun. Hence we may assume that the winds are more rapid on the whole, and of greater violence occasionally, than they would be if India were forest covered. The result would be a slower pace in the latter case than in the former, on the part of the great procession of clouds and saturated air moving up from the ocean, each cloud in fact would remain a longer time suspended over the land of India and the same causes being at work, would naturally discharge in a longer time a greater proportion of its contents. In both cases 90 regiments of clouds enter India day after day from the west during the three months of the Monsoon. In the case of a bare soil, they march across say in 20 days, and in the case of a forest covered soil, they take 30 days to do the same distance, naturally, in the latter case, they are likely to be robbed on the road of more than in the former.

More complete saturation of air over sea.

Once more. This diminution of the general speed of wind must have another effect. We know as a fact that the days out at sea in the Indian ocean are not all cloudy,, even during the

South-west Monsoon season, but that a quite large proportion of them are clear, indicating that the air is not always supersaturated with moisture. Now a slower rate of progression of air over the sea will keep any one square mile or cubic mile of moving air longer exposed to the saturating effect of continual evaporation from the sea below, and a cubic mile of air that has been 30 days coming from the Coast of Africa to that of India is likely to be more fully saturated with moisture than one that has been only 20 days in coming. Hence take the advancing air carried along by the South-west Monsoon as a whole, it is evident that it will arrive on the shores of India more fully charged with moisture when the wind is light that is slow, than when it is strong that is fast, that is to say when India is forest covered than when it is bare.

All these considerations may amount to no more than to point out tendencies, but the sum total of them seems to make out a pretty strong case for thinking that it is most probable the total rain-fall of India forest covered would be considerably greater than if bare, and of course the same would proportionately hold good if instead of the extreme case taken, we had similar conditions but in a less degree, if for instance, we had three-fourths of India forest, one-fourth bare or any other proportion.

Benefit of forests proved.

The above considerations even if they do not convince will perhaps throw some additional light upon the vexed portion of the question of the effect of forests. Those enumerated in the earlier part of this paper are sufficient I contend to prove my case, and whether the reader goes with me or not in the subsequent discussion is on the whole a matter of less practical consequence than might appear from the space I have by the intricacy of the subject been obliged to give it. I trust that the

treatment of the subject will, however, interest some, and lead perhaps to useful discussion.

Interesting subjects suggested.

The effect of the *weight* of the clouds and its play as a factor in the rain-fall question when combined with the barometric power of air to sustain certain weights at certain elevations and only a certain weight at any elevation.

The effect of retardation by a decreasing speed of wind upon a regularly moving succession of clouds in producing rain.

The effect of retardation in increasing the saturation of air coming in from the sea.

The effect of forest in decreasing the speed of wind by reducing the effect of the sun on the land.

The effect of retardation by diminished speed of wind in keeping clouds and saturated air in suspension a longer time over the land.

The effect of the heat radiated from a scorched and bare land in absorbing large quantities of cloud vapor advancing from the sea or in driving up to higher strata clouds advancing in a lower, one by vaporising them from a heavier into a lighter kind of cloud.

The effect of latent heat produced in condensation of vapor into rain, a point which I have taken from Wallace's Tropical Nature.

The effect of mountain barriers generally, and of inequalities in the highest level of an opposing mountain barrier in producing irregularities in rain-fall beyond the barrier.

The effect of unevenly distributed forest or other causes locally affecting heat on land in making local alteration in wind and so causing the disarrangement of the advancing series of rain clouds, and so rain, are all points which are, I think, interesting and worthy of consideration and discussion.

N.-E. Monsoon.

The foregoing pages have been an attempt to trace the causes and effects chiefly observable during the South-west Monsoon. The phenomena of the North-east Monsoon would probably be very similar, mutatis mutandis, the final cause of the whole being the motion of the sun or rather his different position in the heavens. Between these two diametrically opposite winds South-west and North-east at the ceasing of the one and before the commencing of the other it is obvious there must be a dead point, a time spent by the sun in going from the position which gives rise to the one to a position which will give rise to its direct opposite. This period commences from the time the sun begins to get far to the south and continues until he has nearly reached his most northern point. It includes the whole of his absence, comparative absence, I should say, in the south, and it seems most probable that during that time the power he exerts over the land is not sufficient to cause a decided inflow from sea to land in any direction. Not indeed until he has long passed the equator on his northern trip has the heat of the land daily increasing accumulated to such an extent as to produce that general flow of land air upwards which is the immediate cause of the South-west Monsoon. Hence during this period no regular sea wind prevails except locally, and the result is dry weather increasing in heat as the sun advances north until heat reaches the required point to start the general Monsoon wind which brings up the rain clouds that have been gathering over the Indian ocean, to give a double eclát to the first break of the Monsoon.

Forest as the condenser of a distillery.

Reverting once again to the comparison of the whole cosmic agency for the formation and discharge of rain, viz. :—

(1.) Evaporation by the sun's heat on the sea.

(2.) Condensation by a subsequent cooling of the air, or by retardation of wind currents, and consequent excess of weight of moisture beyond what the air can carry—

to a distillery on a grand scale, it appears to be at once clear that whatever increases the power of the condensing part of the apparatus, must increase the total quantity of water condensed, in other words of rain. Anything which tends to cool the air over the land must have this effect, and provided it is not so great or so universal as to prevent the formation of the wind from the sea there seems to be no limit at which the advantage of extending its influence can be shown to stop. Forests undeniably have this general tendency and within the limit above laid down, viz., the cessation of the sea wind by too great cooling of general land temperature it seems certain that they must tend to increase and go on increasing as they extend over larger and larger areas the general rain-fall, and especially so since it has, I think, been shown that a slow rate of air movement, or a gentle wind is more conducive to the bringing over the land of heavily charged cloud masses and excessively saturated air than a strong wind is, while the effect of forest by covering the ground tends to reduce the force or speed of the wind.

Effect of trees in absorbing water from ground.

So far as I am aware there is only one natural fact which can be brought against these conclusions, it is that trees are known to have been planted in marshy places for the purpose of drying up the ground, and with such an effect. One of the extracts above given shows what enormous quantities of sap can be removed from certain trees at certain seasons, and it is no doubt true that for a fast growing tree large quantities of water in the soil at certain times are required, and it follows that if large quantities of water are not available the effect of the

tree will be to dry up the ground by using the water for its own growth ; but supposing this granted, if it is true that the forest produces a greater general rain-fall and protects the fallen rain from the extremely rapid evaporation due to the intense direct heat of a tropical sun, besides many other useful and valuable services of other kinds in almost every conceivable direction may we not allow to the trees themselves as much water as they can get.

Effect of trees in absorbing water from ground.

But it is in the rainy season apparently that trees absorb so largely through their roots, at a time therefore when such adsorption does least perhaps no harm and it is in this season that they do most good by increasing the rain-fall or by preventing the water running away to waste, or returning to the air by evaporation while speaking generally long before the hot season sets in most of such water has percolated down beyond the reach of the roots of the trees. Trees in small patches are not likely to have any appreciable effect upon the quantity of rain-fall, which depends upon conditions affecting generally large areas, and it is quite intelligible that in a generally denuded country where springs of water are low and rain-fall very limited, small patches of trees will diminish instead of increasing the water locally available, the remedy is to plant more, to cover an area sufficiently large to have a permanent effect upon the general distillery, and to condense more from the clouds which from time to time pass over, and so to obtain an extra supply sufficient for the trees themselves, besides economising and rendering more and longer available the original quantity of water.

Trees planted in Marshes.

But again take the case of a marsh dried up by planting trees, the trees will probably be so selected and so planted as to give the least

shade. But a much more important fact is this. The natural peculiarity of marsh land is that it gains little or no addition from falling rain, having a stratum at bottom impervious to water, otherwise it would not be a marsh. Hence the rain, which in ordinary forests is made by the trees to reach the ground slowly, and so as to percolate down into the soil in place of running off, and to sink to lower and lower strata, replenishing distant springs and wells, in the case of the marsh, being prevented from sinking by the impervious subsoil the cause of the marsh, simply accumulates on the surface, and drains away at the surface, leaving no more water in the marsh than there was at first. This limited supply it may be, in the dry season, the trees absorb through their roots and exhale through their leaves to the atmosphere in which it again becomes useful as dew or rain, while the swamp or marsh is perhaps the better for the process, perhaps, if water supply is obtained from it, the worse.

Trees planted in Marshes.

But for the trees and their power of absorbing water the porous spongy soil might have retained water in spite of the hottest sun the upper surface only drying but the lower being protected by the upper as effectually as ordinary soil would be by forest. Areas of peat and marsh or soil of this kind planted with comparatively shadeless trees as the Australian gums in some parts of Ootacamund, or with trees which grow fast, and no doubt absorb much moisture when this is available, may well have had the effect of diminishing the flow of hot weather springs taking their supplies from such sources. If the object be to improve *local* water supply, such places should not be chosen for planting, the more exposed and steeper slopes and the more open soils are best for this purpose; but as the Australian trees are chiefly planted for profit, naturally those spots are

chosen where the ground is found to be most moist and no notice is taken of the fact that these spots do not require protection and are in some cases better off without it.

Springs dried by trees, exceptional and local.

The exception then to the general value of forests will I think on examination of each proved case of this kind turn out to be local and the result of planting with a quite different object to the great one we have been considering, viz., amelioration of climate and improvement of springs and water supply, but it will doubtless be useful to bear in mind that where water is scarce places where trees are likely to diminish, by their absorption, existing stores, should be avoided in planting for climatic purposes, and such places chosen as evidently from the nature of their soil and subsoil, or from the steepness of their slope would not without the help of the forest assist in increasing the general supply of underground water. The shade is as valuable, perhaps more so, in such exposed situations, and rain in the rainy season arrested by the trees and by the spongy soil accumulating at their roots, will penetrate into the ground, rapidly sinking beyond the reach of the roots, if the soil be sufficiently deep and not too retentive of moisture, and all that does so penetrate will become available afterwards at lower levels in springs or wells, perhaps many miles distant, but in any case useful somewhere, while a marsh filled by one heavy fall of rain can hold no more and all the rain that falls on it afterwards must overflow and run off its surface just as it would on land bare of trees.

Appendix A.

Appendix A contains a statement showing the average temperature of groups of stations (1) at the sea side, (2) inland, (3) further inland for all the months in the year and shows the gradual increase of heat in

the hot weather and of cold in the cold weather as one goes inland.

Appendix B.

Appendix B is a statement showing the average diurnal velocity of the South-west Monsoon wind in miles for groups of stations for the South-west Monsoon months of May, June, July, August, and September, 1879.

I. At the Sea Coast when stopped by an opposing barrier of high mountains,

II. At the Sea Coast when no such barrier exists,

III. Some way inland from the West Coast,

IV. Further inland,

V. Still further inland

and shows the gradual decrease of speed or retardation of wind referred to in the above discussion as one follows the course of the South-west wind from South-west and North-east across India. In both appendices the figures are taken from the report on Meteorology of India for 1879, by H. F. Blanford, F. R. S.

# APPENDIX A.

## Thermometer Averages.

| Stations. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vizagapatam ... | 76·1 | 79·0 | 83·4 | 86·3 | 87·9 | 87·8 | 85·2 | 85·3 | 84·8 | 83·2 | 79·5 | 75·4 | 82·8 |
| Madras ... ... | 76·5 | 78·4 | 82·0 | 85·0 | 87·5 | 87·3 | 85·7 | 84·9 | 83·9 | 81·3 | 78·3 | 76·6 | 82 3 |
| Cochin ... ... | 78·9 | 80·6 | 82·5 | 83·7 | 82·3 | 78·3 | 78·1 | 78·0 | 78·5 | 79·1 | 79 9 | 79·0 | 79·9 |
| Average... | 77·1 | 79·3 | 82·6 | 85·0 | 85·9 | 84·4 | 83·0 | 82·7 | 82·4 | 81·2 | 79·2 | 77·0 | 81·6 |
| Trichinopoly ... | 76·5 | 79·1 | 84·0 | 87·5 | 87·5 | 86·5 | 85·7 | 84·4 | 83·4 | 81·1 | 78·8 | 76·7 | 82·6 |
| Salem ... ... | 76·7 | 79·6 | 84·4 | 87·3 | 85·5 | 83·4 | 82·1 | 81·3 | 81·1 | 80·0 | 78·5 | 76·4 | 81·4 |
| Bellary ... ... | 73·4 | 78·6 | 86 1 | 89·2 | 88·5 | 83·5 | 81·4 | 80·8 | 80·2 | 79·5 | 75·9 | 73·1 | 80·8 |
| Average... | 75·5 | 79·1 | 84·8 | 88·0 | 87·1 | 84·4 | 83·0 | 82·1 | 81·5 | 80·2 | 77·7 | 75·4 | 81·6 |
| Delhi ... ... | 56·8 | 61 6 | 74·1 | 83·0 | 89·0 | 93·7 | 88·8 | 86·4 | 84·5 | 78·0 | 69·0 | 59·6 | 77·0 |
| Allahabad... ... | 60·1 | 65·7 | 77·5 | 87·1 | 92·1 | 91·4 | 85·1 | 83·4 | 83·0 | 77·7 | 68·1 | 60·5 | 77·6 |
| Jubbulpore ... | 61·9 | 66·4 | 75·4 | 84·4 | 90·2 | 87·3 | 79·1 | 78·1 | 78·6 | 74·1 | 66·1 | 61·4 | 75·3 |
| Nagpore ... ... | 68·7 | 73·9 | 81·7 | 88·4 | 92·8 | 86·5 | 79·1 | 78·9 | 79·2 | 77·0 | 71·0 | 67·5 | 78 7 |
| Average... | 61·8 | 66·9 | 77·1 | 85·7 | 91·0 | 89·7 | 83·0 | 81·7 | 81·3 | 76·7 | 68·5 | 62·2 | 77·1 |

Statement showing average temperature of groups of Stations a, the sea side, inland, and further inland, for all the months in the yeart

showing gradual increase of heat in the hot weather and of cold in the cold weather as one goes further and further inland.

*N. B.*—The extremes or maxima and minima upon which the above means have been calculated would show a far greater difference in the same direction.

Figures taken from Report on the Meteorology of India for 1879, by H. F. Blanford, F. R. S.

## APPENDIX B.

| | Stations. | May. | June. | July. | August. | September. | Average. |
|---|---|---|---|---|---|---|---|
| I. | Cochin... ...<br>Goa ... ... | 46 | 40 | 32 | 35 | 29 | 36 |
| II. | Bombay ...<br>Surat ... ...<br>Kurrachi ... | 282 | 382 | 337 | 384 | 259 | 329 |
| III. | Madura ...<br>Salem ... ...<br>Bangalore ...<br>Bellary ...<br>Nagpore ...<br>Jubbulpore ...<br>Agra ... ...<br>Delhi ... ... | 120 | 154 | 118 | 124 | 128 | 129 |
| IV. | Trichinopoly ...<br>Sironcha ...<br>Raipur ... ...<br>Allahabad ...<br>Lucknow ... | 98 | 106 | 87 | 96 | 81 | 94 |
| V. | Sambulpore ...<br>Patna ... ... | 41 | 26 | 34 | 62 | 42 | 41 |

Statement showing average diurnal velocity of wind in miles for groups of stations for the months of May, June, July, August, September 1879.

I. At the Sea West Coast when backed by high barrier of mountains.

II. do. do. when open to the East.

III. Inland—from West Coast.

IV. Further inland.

V. Furthest inland and near supposed origin of wind.—

Showing gradual decrees of speed or retardation along direction of general wind course towards the North-east.—

Figures taken from Report on Meteorology of India 1879, by H. F. Blanford, F. R. S.

# ADDENDUM.

The following report republished in the *Fort St. George Gazette,* by order of the Right Honorable the Governor in Council will be read with interest as the views of a trained and scientific forest Professor upon English and Scotch woods and forests. I have put in italics those portions which seem to me best to illustrate the questions which are of most importance to us here: the reader must not forget to substitute "cattle and goats" for "sheep and deer" in applying to this country remarks made upon Scotland and England.

## REPORT OF A VISIT TO THE ENGLISH AND SCOTCH FORESTS BY THE PROFESSORS AND STUDENTS FROM THE NANCY FOREST SCHOOL.

By M. Boppe, Inspector of French Forests.

The total area of Scotland is about 20,000,000 acres, hardly one quarter of which may be reckoned as arable, forest, or pasture land, the remainder being occupied by the lakes, rivers, peat-mosses, moorlands, bare rocks and mountains. It is surprising then to find that against such a vast area of uncultivated ground only 734,490 acres, according to the official returns of 1872, are classed as woodlands.

There is every reason to suppose that, at a remote period, both the Highlands and Lowlands of Scotland were covered by dense forests, which were successively destroyed by the fire and steel of conquerors and during the anarchy existing under the old feudal system, as well as by the fearful storms which at almost regular intervals sweep over certain districts. So complete, indeed, was this devastation, that, in 1707, all that remained of the grand old Caledonian forests were a few shreds, and those in a most deplorable condition.

From the union of the two kingdoms dates a period of political calm, during which, time and the marvellous timber-producing properties of the soil and climate would have done much to repair the ruin, *had not the sheep, arch-enemy of all forest vegetation, been allowed to retain his footing in the forests.*

The noblemen and great landed proprietors of Scotland at last felt the necessity of doing something to restore the parks and woodlands in the immediate vicinity of their mansions, and by the introduction of plantations to vary the sombre monotony of the boundless heather.

It was also necessary on these bare moors, where grazing and shooting form the main sources of revenue, to furnish shelter for the cattle, sheep and deer. Their example was soon followed by the smaller proprietors, and, under the wise patronage of the "Select Society" of Edinburgh, founded in 1754, the area of forest land augmented rapidly, so that in 1812 Scotland possessed, besides 500,000 acres of natural forest, about 400,900 acres of plantations.

The year 1815 marks a pause in the work of replanting which had been so vigorously begun. We do not pretend to enter here into the various causes which led to this economical phenomenon, but it is certain that the laws of 1636, on the constitution of landed properties in Scotland, exercised a baneful influence on the rational cultivation of the soil. The Scottish Parliament in vain sought to counteract the Draconian regulations of these laws, the principal effect of which was to cause the proprietors to look on themselves as only life-tenants of the entailed estates, and consequently to take but a very slight interest in the improvement of the soil and the augmentation of its pecuniary value.

From the moment the planting ceased the area of woodland diminished, and necessarily so, for in any forest where sheep have free entrance the removal of a tree, whether by the axe of the wood-cutter or by the violence of the wind, causes an empty space which can only be refilled by resorting to artificial means. It is thus that the returns of 1872, as compared with those of 1812, show a diminution of some 200,000 acres in the area of forest land in Scotland. Whether it was a portion of the old natural forests or the newly planted ones that had disappeared during this period of 60 years, the documents extant do not show. There is, however, good reason to suppose that both suffered equally in this respect. For, on the one hand the construction of the Highland Railway necessitated the employment of a large number of sleepers, which could be procured from the woods of from 50 to 80 years of age, along the line of route; and, on the other hand, the increased facilities of transport, and the scarcity of wood in England, gave an unexpected value to certain tracts covered with birch, and so tempted many of the proprietors to cut down the old forests composed of this species.

In 1870 the work of replanting seems to have recommenced with increased ardour, and on all sides may be seen young plantations vigorously striving to fill up the gap which separates them from those of half a century's standing.

Such, in a few words, is a brief outline of the history of the forests which we have had the good fortune to visit, under the guidance of our excellent friend Colonel Pearson. Thanks to the kind forethought of the authorities at the India Office, and to the hearty welcome which we everywhere received from the great landowners and their agents, our flying visit was accomplished in a most agreeable and instructive manner. We eagerly seize this opportunity of offering to all concerned with it our sincere and hearty thanks. We would fain also express to the eminent personages who did us the honor of receiving us so graciously, that we accepted their kind marks of attention as being addressed, not only to ourselves, but also to the French Government and the Forest School at Nancy, which

year by year, since 1868, has offered to the English students, without any distinction of nationality, the advantages of a forest education.

Before proceeding to a description of our tour, it will perhaps render the narrative more intelligible if we give a brief sketch of the country we visited, its general aspect, and natural resources.

From a forest point of view, Scotland may be divided into two distinct regions, by an imaginary line drawn from Perth, on the Firth of Tay, to Greenock, on the estuary of the Clyde. To the south of this line we find the Lowlands, a country which agriculture and manufactures have combined to render one of the richest in the world. The economic situation of this wealthy district is as prosperous as possible, and the thoroughly developed system of high farming which is there employed leaves but little room for forest cultivation. The Lowlands are bounded on the south by the Cheviot Hills, which afford excellent sheep walks. To the north of this line lie the Highlands, intersected in all directions by the far-stretching chain of the Grampians, whose rugged nature gives to the country an aspect not unlike that of the western coast of the Scandinavian Peninsula. One would imagine that at some earlier geological period immense polar glaciers, flowing over the solidified North Sea, traversed the whole of the north of Scotland, polishing on their way the mountain sides, excavating the lake beds, and breaking off abruptly the cliffs surrounding the coast. The culture of cereals is here confined to a few favoured localities, situated near the mouths of the rivers or on the low-lying ground bordering the sea, where the glacial deposits constitute an excellent soil. The rest of the country is wholly occupied by water and heather ; and thus out of the 13,000,000 acres which this region comprises, only 1,600,000 (or less than one-eighth) are classed as arable, forest and pasture lands. If out of the remaining 11,000,000 acres of unproductive land we allow a half for the lakes, bare ridges, and sterile mountain tops, there will still remain 5,000,000 acres capable of furnishing valuable timber forests. Here then is a problem for British economists, and a vast field for enterprise and capital.

Highland Forests.

In the Highlands, to which we principally directed our attention, the districts around Perth, Elgin and Inverness are those in which the most extensive forests are to be found. These three countries together contain about 247,700 acres of forest, and being well served by the Highland Railway system, these are easier to visit than any of the other Scotch forests. Starting from Perth, we made our way across the Highlands visiting *en route* the towns of Dunkeld, Blair Athole, Aviemore, Grantown, Forres, Inverness and Beauly. We were thus enabled not only to make an inspection of some of the finest forests in Scotland, but at the same time to obtain a fair idea of the general aspect of the country. The punctuality and precision, so thoroughly characteristic of Englishmen, with which all the details of our journey were arranged by Colonel Pearson, added to the hearty reception we met with at every turn, enabled us, in the short time at our disposal, to thoroughly inspect more than 100,000 acres of every description of forest, under ever-varying physical and geological conditions. Everywhere, both at a few feet above the sea level and on the sides of mountains at a height of 2,500 feet, in the

sands of Forres and in the Schists, red standstones, granites and gneiss of the interior, we were struck by the wonderful aptitude of the soil to forest vegetation, favored as it is by a regular climate and the constant humidity of the atmosphere.

In the low-lying districts, at an altitude of from 250 to 300 feet, we found growing, both singly along the roadside and collectively in the forests, magnificent specimens of oak, maple, elm, ash, beech and lime, which, by the vigour of their growth and the rich coloring of their foliage, bore testimony to the favorable conditions of soil and climate under which they grew. We were struck with admiration in beholding the colossal trees of every description forming the avenues at Scone, Dunkeld, Blair Athole and Darnaway. It was near the first of these places that the venerable father of Scotch forestry, Mr. McCorquodale, showed us, with legitimate pride, a small oak forest of about 400 acres, which, 60 years before, he had himself assisted to plant. In this forest, the trees were standing about 24 to 30 feet apart, and their diameters measured from 12 to 18 inches, whilst their magnificent tops formed a perfect canopy of leaves above the bright rhododendrons, in which colonies of young pheasants found a home. In the spring time this ought indeed to be a fairy-like spot. But independently of this undergrowth, which is, after all, only suitable for the wealthy few, we cannot help thinking that a more careful study of this superb forest would go far towards clearing up some of the doubts which have always surrounded the difficult question of the cultivation of forests composed solely of oak.

The mountain vegetation commences at about 400 feet above the level of the sea; beyond this we find ourselves in the domains of the Scotch fir, the larch and the birch.

In selecting the Scotch fir as the tree to be cultivated before all others in these regions, the promoters of forest plantation during the latter half of the past century showed no mean proof of their thorough appreciation of the natural requirements of the soil and climate of the Highlands, for not only have they ensured the success of their operations, but they have traced out the best line of action for their successors.

Equally fortunate were they in their endeavour to introduce the larch into Scotland; transported from the ice-bound summits of the Alps to a country where the climate is tempered by the softening influence of the Gulf Stream, this tree does not appear to have suffered to any material extent by so sudden a change of latitude.

When, in 1737, the Duke of Athole brought home, amongst his baggage, as a kind of remembrance of his travels in the Tyrol, the seeds which were sown in his park, and from which sprung the first larches in Scotland, he rendered a most valuable service to his country.

From a forest point of view, the results obtained by the cultivation of these two species (Scotch fir and larch) are truly marvellous. Any one who has seen the beautiful larch forests planted in 1815 on the banks of Loch Ortie and the vast stretches of Scotch fir covering the flanks of the Bruarwood Mountain, cannot fail to admit that the question of the replanting of the Scotch Highlands is practically answered.

The absence of the beech from all the forests of any standing is easily accounted for by the fact that it is only quite recently that the timber of this tree has become of any value for industrial purposes. For many cultural reasons, however, the beech is a tree of the highest importance, and we should strongly recommend its introduction into all future plantations; and it is, moreover, as much indigenous as the Scotch fir and birch. In many cases even it might with great advantage be substituted for this latter, or, better still, mixed with it.

Considering, too, the wonderful success that has attended the introduction of the larch, we think that a similar attempt might be made to acclimatize the *Pinus montana* in the peat-mosses. These immense sponges, so to speak, which cover sometimes entire districts, discharge their dark-colored waters into all the streams, and give to the lakes and rivers of Scotland that sombre tint which is so peculiar to them. The fuel which they afford is of very second-rate quality; and supposing that half the surface was converted into plantations, there would still be enough peat left to keep going all the whiskey stills on the country side.

As foresters of the Continental school, accustomed to live among forests regularly managed, and having for their sole object the production of timber, *we had no little difficulty in understanding the widely different motives which actuate forest cultivation in this country. Everywhere we found the forests fenced in on all sides with walls and hedges; and, as a matter of fact, the forester or agent generally carries the keys of the gates in his pocket. We learnt that these costly enclosures were erected, not for the purposes of keeping out the cattle and deer, as in the Jura, but for the purpose of keeping them in; it appeared to us like shutting up the wolf in the sheepfold.*

We were also struck by the monotonous regularity in the height and age of the trees—unmistakeable sign of their artificial origin and want of methodical management. The forest, here left to its own devices, continues growing just as the hand of man has planted it; *the undergrowth is constantly grazed down by the sheep and cattle, and nature, in spite of the immense resources at her disposal, is quite powerless to modify the work of the planter, or repair the errors committed by wood-cutters.*

*When, under such circumstances, the time arrives for the trees to be cut down, or should they be uprooted by a hurricane, the forest disappears in its entirety, owing to the total want of young growth which is necessary as a link between the old forest and the new one which ought to be created.* Such, at least, appears to us to be the case in all the forests that we visited in the valley of the Tay and its tributaries, and further north, near the foot of Cairngorm.

Not far from a mansion to which are attached some of the pleasantest recollections of our tour, we saw the remains of a noble forest, which some 20 years ago had been cut down and converted into railway sleepers. The sight of the huge stumps, blackened by time, with their gnarled roots twisting themselves over the ground, gave us the idea of some vast charnel house. This scene of utter ruin was indeed a sad spectacle, though the present proprietor is doing his best to again cover his estate with timber; with a better system he might have been spared both time and expense. It is

easy in Scotland to perpetuate a forest by natural means, and of this a practical proof was given us in two forests which we visited—the one near Grantown, in Strathspey, the other at Beauly. *In these the results obtained under the skilful and intelligent direction of the gentleman who manages these forests for their employers form a striking example of what may be done in the way of reproducing forests by natural means. In fact, nothing had been neglected which even the most critical forester could desire; the gradation of age was here complete, and the reservation of specially vigorous trees, of known pedigree, duly carried out.*

*The modus operandi here pursued consists simply in the exclusion of the sheep and deer, in the judicious thinning out of the growing crop, and in the removal of the mature seed-bearing trees, by successive fellings, as the young forest grows up and acquires more vigour.*

*Nevertheless, we would not have it be supposed that the sheep need be absolutely debarred from all grazing in the forest; it is only in those portions where the undergrowth is very young that the damage caused is irreparable. We feel convinced that if, every year, certain portions of the forest best capable of supporting it were marked out for grazing, the quality of the pasturage would be greatly improved, and the heather would quickly disappear under the cover.*

*It is an established fact, beyond all contradiction, that on any soil, whatever its geological origin, a complete covering of forest vegetation will kill the heather as soon as the trees reach the age of between 30 and 40 years. Suppose then that 120 years be the term fixed for the existence of the trees in any portion of the forest, and that the trees of 100 years of age and over are reserved, there would still be one-half of the forest always open to the sheep, and the other closed. But at the same time, it is certain that this open half, owing to its superior quality, will furnish pasturage for at least twice as many head of cattle or sheep as the same quantity of moorland.*

*Although, under ordinary conditions, the regeneration of a forest will be sufficiently assured by the exercise of a discreet control over the grazing, something more than this must be done if it is desired to turn the land to the best possible account.* It is therefore a matter of regret that nothing has yet been done to place forest management in Scotland on a sound economic basis.

The productive powers of the soil and of the climate have been made use of by able and intelligent planters, who have thereby enabled nature herself to accumulate a considerable store of timber; but all this wealth is exposed to the carelessness of some and to the ignorance of others, until the hand of a forester manages it properly and places it on the only sound economic principle of all agricultural and forest property,—*a constant annual revenue and a constant improvement in production.*

It would certainly not be fair to hold the Scotch foresters responsible for the present regrettable state of affairs, for, though they have for the most part admitted the inefficacy of the present system, they are powerless to effect any improvement so long as the landowners and general public have not learnt to appreciate the manifold advantages to be derived from a regular and methodical management. They have to struggle against many adverse interests and hin-

drances, such as grazing and shooting interests, questions of routine, pecuniary exigencies and the fancies of sportsmen from all parts of the world.*

In wishing Scotland, then, a hearty farewell, we venture to predict for her forests a great and prosperous future. It does not need that one should be a very great prophet to predict this for a country where the oak and beech, the Scoth fir and larch, flourish with equal vigour, and where the *Abies Douglasii, Abies nobilis, and Abies Menziezii*, the *Sequoia* and the cedar, form mighty trees in company with *Araucaria* and various exotic shrubs, which only languish miserably under the climate of Paris.

Before leaving this country, however, we would fain add a word of advice, for the moment appears to us a propitious one for deciding on the future welfare of the forests, which, owing to the rapidly increasing value of timber, runs great risk of being compromised. Ordinary fir timber now fetches 8*d*. per cubic foot: larch is worth nearly double that amount. We ourselves visited a forest of Scotch fir which, at this rate, would be worth £120 an acre, and another of larch worth considerably more; whilst a third forest of 1,600 acres, composed of Scotch fir, was purchased a few years ago for £52,000, or only about £30 an acre. The plantations on the Culbin Sands, near Forres, would readily find buyers at £50 an acre at the age of forty-five to fifty years. The very day we were at Grantown, the agent for the Strathspey forests concluded a bargain to furnish birchwood to the amount of £2,000.

All these figures are fraught with extreme significance for the future, and the large forest owners of Scotland will do well to pause before allowing their forests to be "overworked." We would recall to their recollection the old fable of the goose that laid the golden eggs.

No doubt, people are often frightened by the long names and big words they find in treatises on scientific forest management, but they may very well neglect the text if only they will adopt some of the principles which they contain. *Let the owner of a forest, after having made a careful and detailed inspection of it, divide it of into blocks or compartments so arranged that they should be uniform as regards conditions of soil and of planting, and then proceed to count and measure all the trees of 3 feet girth and upwards, classing them in categories according to their diameter. He should then open a debit and credit account for each compartment, placing on the debit side the actual volume of the standing crop, and on the credit side the volume of timber removed at each successive felling. This register should always be consulted before undertaking any forest operation, and when the annual fellings fall due, it will show which compartments can best support the withdrawal of timber, and which require to be left untouched.* Moreover, the balance sheet will render an exact account, favourable or otherwise, of the condition of the forest.

Ten years of such systematic treatment would form in itself the

* A deer run, over unproductive land, has just been let to an American for nine years at the fabulous rent of £10,000 per annum.

basis of a regular forest working plan, and the doctor's prescription would no longer frighten the patient with its long words.

Our programme, however, was not yet complete, and fresh excursions awaited us in England. It took us only four days to reach Windsor Forest from Inverness, passing by the Caledonian Canal, and halting at Oban (from whence we visited Staffa and Iona) and Edinburgh, whence we took the train to London.

Windsor Forest.

Even with a four-in-hand and the best of drivers, it would be impossible to see Windsor Forest in such a short time as we had at our disposal.

The history of that noble park has been published in a splendid volume by the late Surveyor, but the history of Windsor is, so to say, a repetition of the history of England herself. If we follow all the phases in the development of this park, where, since the time of William the Conqueror, each sovereign in turn has given his name to some remarkable tree, Windsor Park may with justice be called the Westminster Abbey of British monumental trees; its history is one which belongs as much to archæology as it does to sylviculture, while in it the beautiful deer are almost as numerous as the trees themselves.

Nevertheless, the practical forester may rest assured that, although the first place is here given to art and beauty, he will still be able to find much to interest and instruct him. Windsor Park is indeed one of the most magnificent fields for the study of forest botany that even the wildest imagination could conjure up. Here may be seen, growing singly or collectively in clumps, specimens of all the finest trees, native or exotic, which exist in Great Britain, and, since care has been taken to keep an exact record of the age and origin of each plantation, the forester would be enabled to follow out in detail studies of the highest interest and importance regarding the growth of the principal forest species. It would be more difficult to do the same with regard to their longevity; for one is led to think, in looking at some of them, that, in this hallowed ground, trees never die of old age. One sees in these relics of the past, that religious respect for things so characteristic of Englishmen, when even the most violent revolutions could pass over the country and yet leave these monuments and these trees intact.

The Surveyor of Windsor Park, who is, by turn, a forest officer, an organizer of shooting parties, a director of the royal workshops, and Conservator of a museum of antiquities, can, in consequence, have but little time to devote himself to sylviculture, unless it be to prepare the iron armour, intended to preserve the veterans of the forest in their struggle against the elements, or to prop up with crutches some invalid deprived of a limb by a recent gale.

Having come all the way from Scotland to Windsor, we were not to be alarmed by the journey from there to the New Forest, for a few hours sufficed to carry us to Southampton.

New Forest.

As old as Windsor Park itself, the New Forest has not had the good fortune to be the dependence of a royal residence. The barrenness and poverty of the soil has sufficed to preserve it from being plundered even at an epoch when land was valued more for its extent than its fertility. But, on the other hand, this very

fact attracted a poor and necessitous population to settle in and around the forest, who, during long ages, have been accustomed to derive a precarious existence from it, and by careless abuses have threatened it with certain ruin. *For many centuries the New Forest has thus been a prey to commoners, who use up its resources without either method or control. One may see there the steady onward progress which is made by the heather; and, although it is not perhaps so quick under the feet of the almost wild ponies and cattle as under those of the sheep, yet it is none the less sure.*

*The sole remedy for this state of things was to restrict the commoners to certain defined localities, and that could only be done by sacrificing a portion of the forest to save the rest. This is, in fact, what was done about twenty years ago;* but the sacrifice has indeed been a heavy one, for the reservation of some 14,000 acres has cost the abandonment of 49,000 more. The part which has been freed, however, is sufficiently extensive to constitute some day a respectable forest, whilst the part given up is hurrying to its destruction in a manner deplorable to behold, and, before very long, there will be nothing left but a worthless barren heath.

It is not, however, in 20 years that a forest so badly used as the New Forest can be restored. The first thing to be done was to put the soil in good order, and then to plant some of the vast stretches of heather with firs. *Of late years the forest officers have sought, by excluding the cattle, to bring about the natural reproduction of some portions hitherto abandoned to pasturage. But with whatever care these operations may be carried out, at least 50 years must elapse before they can resort to systematic fellings, with a view to furnishing a regular revenue.*

At present, contiguous portions of the forest often present the most curious contrasts. On one hand we see young firs and oaks growing side by side, in another place a forest of pure oak, languishing among chestnuts, and in a third plantations of fir and beech, indicating by the vigour of their vegetation, and their healthy appearance, that it is on them that the future of the forest ought to depend. Further on there is a valley filled with aged beeches, whose weird forms gave an almost supernatural aspect to the spot; we almost expected to see the ghost of William Rufus pursuing that of Walter Tyrrell through the haunted forest.

Without contesting the marvellous beauty of some parts of the New Forest, so dear to artists and lovers of nature, we are bound to say that before long it will *not be here* that a professor of sylviculture, desirous of teaching his science, will choose to pitch his tent.

Forest of Dean.

On our return to Lyndhurst, after the excursion in the New Forest, there remained but three days at our disposal before our duties necessitated our return to France. These were employed in visiting the Forest of Dean.

The present Forest of Dean occupies the site of the old forest of the same name, which formerly covered the whole of the plateau between the estuary of the Severn and the valley of the Wye. ("Dean," "dên," signifies "forest" in the old Celtic language.) The old forest has disappeared within the last few centuries, owing perhaps to the demand for charcoal and mine-props for the local industries;

if, however, we were not afraid of being accused of being prejudiced, we might say that unrestricted pasturage may have had something to do with the disappearance. It is on these ruins that the new Forest of Dean has been created; in less than a century more than 16,000 acres of the original 22,000 have been replanted. The older plantations are generally of pure oak; the beeches, chestnuts and birches form but a small percentage of the trees. Scotch fir, spruce fir and larch are generally only found in the plantations made during the last 30 years or in bad peaty portions. The state of vegetation is generally good, varying, however, with the quality of the soil, but indicating in every point the artificial nature of the forest.

We may take this opportunity of remarking that a plantation of "broad-leaved" trees (oak, beech, &c.,) takes a much longer time to establish itself than one of "needle-leaved" trees (conifers,—Scotch fir, larch, &c.) In Scotland we saw the most magnificent plantations of larch and fir, whilst in the Forest of Dean the plantations of oak were always more or less dwarfed in appearance. The cause of this is that oaks furnish the soil with much less vegetable manure than the coniferous trees; and again, in an oak plantation there is a marked absence of under shrubs and spontaneous ground vegetation, which, by their organic remains, tend to increase and improve the surface soil. It is rare also that a plantation of oaks, on a soil which has been long unoccupied by forest vegetation and is but moderate in quality, succeeds well during the first generation; it is only at the second generation that the trees acquire their normal development.

At present, while the trees are yet in their youth, the only cultural operations that can be undertaken are the periodical "thinnings," and these are here conducted with great skill. There is, no doubt, however, a great future in store for the Forest of Dean, thanks to the workmanlike manner in which it is managed, and to the laws regulating the pasturage which date back to the time of Charles I.

We were not able to suppress a certain vague feeling of sadness in wandering through these endless plantations, rendered so dreary and monotonous by the total absence of that undergrowth which seems to inspire the woods with freshness and life; and it was with a sense of great relief that we emerged from them, and entered into a well managed forest composed of standard oaks surmounting coppice wood.

This forest, comprising about 3,400 acres, was formerly the property of Lord Gage, and was purchased by the Crown with a view to presenting it to the Duke of Wellington. It is composed of pure oak, and for more than 100 years the coppice has been cut every 18 years. We might add that the reserved trees form the staple element in this forest, for the coppice forms but a small proportion of the standing crop. These reserves, varying in age from 20 to 100 years, are in an excellent state of vegetation, and number about 80 trees to the acre. The largest trees are about 4 or 5 feet in girth, and from 25 to 35 feet in height of stem. It would be a great pity to cut them until they have attained at least double their present age. This forest would form an excellent field for the study of the treatment of standard oaks.

In such a forest, w[illegible]e the soil is so exceptionally fertile, it might

be possible to find a solution to the oft-discussed problem of obtaining the maximum production in quality and quantity from a forest of oak. This was, at least, the impression we carried away with us as we turned our faces homewards.

Forest School in Great Britain.

We had barely sufficient time on our arrival in London to pay our respects to the authorities at the India Office, when we were asked by Sir Louis Mallet to place on record the observations which we have now the honor to submit, and to state whether, in our opinion, the immediate foundation of a Forest School in Great Britain is possible. In order to reply to this question, it was necessary for us, even at the risk of our narrative being found tedious, to enter into a somewhat detailed account of the Scotch and English forests.

Were it only for the purpose of replanting the five or six millions of moor and waste land which cover one-third of the Highlands, we should consider there was a sufficient reason for the formation of such a school. The question, however, must be studied on broader grounds.

*Considering the present depressed state of agriculture all over Europe, it becomes more and more necessary to endeavor to draw the greatest possible advantage from the land, and, by properly adapting a different vegetation to different soils, to seek to obtain, through the medium of the enormous capital which the present generation can command, the maximum production from a minimum area.* It is *thus that the forests are called upon to play an important part in the immediate future*, and the farmer will henceforth find a powerful auxiliary in the forester.

After making every allowance for the great fertility of the soil in Great Britain, we feel certain that in many districts more than one of the forests which were cleared sometime back would now be jealously preserved by the same proprietors who formerly cut them down to satisfy their pressing wants.

It must also be borne in mind that the British Empire is not confined to great Britain and Ireland, and that, by reason of her immense possessions, England is, perhaps, of all nations in the world, the one most richly endowed with valuable timber forests. It is by hundreds of millions of acres that we may reckon the forests of Canada, India, and Australia, New Zealand and Cape Colony, not to speak of those in the West Indies and Borneo.* All these natural sources of wealth are worked by British enterprise and British Capital, and, consequent on the present wonderful development of commerce throughout the globe, it is a matter of importance to every civilized nation that this vast accumulation of forest riches should not fall into the hands of ignorant persons, or be squandered away regardless of the future.

For these reasons the establishment of a Forest School in England becomes a matter of primary importance.

The science of forestry is, however, a science of observation, based

* The total extent of the forests in the British possessions is 340,000, 000 acres of timbered land.

upon facts which must be studied both from a practical and theoretical point of view. It is therefore absolutely necessary that a Forest school should have attached to it a forest which has for some time past been under scientific management, serving, so to speak, as a natural laboratory for experiments, and without which the best theoretical teaching in the world would be of no avail. This is especially the case in England where the young men, by reason of their national character and their mode of education, are accustomed to pay more attention to facts than to theories; here the teacher of a technical profession, resting solely on theories, would command very few disciples.

Necessity for a Reserved Forest.

It is, therefore, a matter of regret that, among all the forests visited by us in our travels, there is not a single one suitable for the teaching of sylviculture on that broad basis so essential when the pupils are called upon to apply it in all quarters of the globe. In England, as in Scotland, all the woodlands may be arranged in two categories—the one containing plantations too young, recently created by the hand of man; the other containing plantations too old, or too much overworked, to be useful for the purpose; nowhere did we see a high timber forest formed of really mature trees.

Moreover, a plantation must always be incomplete as a field of study, and especially for persons who will generally have to deal with natural forests. Nature, ever prodigal of her bounties, if left to herself scatters them broadcast without any regard for the particular wants and requirements of man. It is then the work of the forester to control this generous prodigality, and, by careful selection, to concentrate her fertilizing powers on such trees as are best adapted to meet the general demand. In the case of a plantation there is no need for this interference; here, natural selection, the struggle for supremacy amongst the different species, and even art herself, can play but a very insignificant part in the various phases of its existence.

Natural forest required.

In a forest, then, of this nature it would only be possible to apply a very limited number of the principles of sylviculture.

A practical Englishman will have no difficulty in understanding our meaning.

It is not to be supposed, however, that the foundation of a Forest School is at present an impossibility; for, while leaving the question of time and place to be settled hereafter, it would be advisable to at once decide, in principle, on its creation; such a decision is the only mode of arriving at its foundation. It is necessary also to take measures for preparing the public mind to regard the science of sylviculture as an additional means of developing the national resources, and to take steps for the gradual creation of accessory forests.

This accessory forest must necessarily be incomplete at first, but would be perfected in time; but the essential point is that it should be placed under the absolute control of the officers of the school. This can only be done by choos-

Under control of Forest officers.

ing a State forest. If it should be considered desirable also, in order to render the teaching more complete, the State ought to purchase or lease in Scotland a forest suitable for the purpose.

Professors of Forest Economy.

We would also suggest the founding of Professorships of "Forest Economy" at two of the great public seats of technical instruction. One of these might be instituted at Coopers Hill for England, the other at Edinburgh for Scotland.

The Professors should be selected from among the young men who have received a thorough forest education on the Continent, and have had eight or ten years' practical experience in India. They should publish from time to time a series of articles in the leading agricultural and forest journals, in order to influence the landowners in favour of a systematic management of their woodlands, and to prove to them that uncontrolled pasturage is the certain destruction of forests, and that, in the long run, the timber furnished by forest land is of greater value than pasturage or game.

The establishment of a course of Sylviculture at Coopers' Hill would have the great advantage of giving to the young Engineers a rudimentary knowledge of a science which cannot fail to be useful to them in their after-career. It would, perhaps, also be possible by this means to modify the present method of recruiting the Indian Forest Service, by offering to the students at this excellent institution a certain number of appointments in that service.

The course of instruction afforded at Coopers Hill would then comprise all the essential parts of the education of a forester, and it would only be necessary to supplement it by sending the selected students for one year to a Continental school, where they would have the opportunity of perfecting themselves in the practical details of forest culture. After this it would be advisable for them, accompanied by their English Professor, to complete their training by making a tour of inspection in some of the mountain forests of France, Germany and Austria. So prepared, the young men would be perfectly capable of undertaking forest work in any portion of the Indian Empire.

Recommendations.

In conclusion, we beg to submit the following recommendations :—

1st.—That a National Forest School be founded in Great Britain.

2nd.—That Professorships of Sylviculture be instituted at Coopers Hill and at Edinburgh.

Such are the conclusions at which w in conjunction with our travelling companions, Messrs. Reuss and Bartet, have arrived, and we feel that an apology is due for their length. This is really due to the excessive courtesy of our hosts, who, jealous of the success of Jules Verne's hero, who made the tour of the world in 80 days, were determined to make us traverse, in less than three weeks, more than 300,000 acres of forest land situated in the most opposite parts of Great Britain, from Cape Duncansby to St. Catherine's Point.

(Published by order of the Right Honorable the Governor in Council).

E. F. WEBSTER,

*Secretary to Government.*

